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Status and Estimated Life of the 300,000-Gallon INTEC Tanks

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SUMMARY

Historically, mixed (radioactive and hazardous) liquid wastes generated at the Idaho Nuclear Technology and Engineering Center (INTEC) has been stored in the Tank Farm after which it is calcined. The resulting calcine has been stored in stainless steel bins. Because the vaults, which contain the Tank Farm tanks, do not meet all of today's regulatory criteria, the State of Idaho is concerned about possible leakage to the environment. Because of this concern, the Third Modification to the Notice of Noncompliance Consent Order (NONCO) required that by July 31, 1999, DOE submit to the Idaho Department of Environmental Quality a report detailing the past studies, current status and estimated life of the eleven 300,000-gallon INTEC tanks, and ancillary equipment, based upon existing data. That report was issued on schedule.

The Third Modification to the NONCO also required that by November 15, 1999, DOE update the July report to include a detailed long-term plan and schedule for inspection and corrosion coupon evaluation for the tanks, a corrosion evaluation of the visual data from the Light Duty Utility Arm entry into Tank WM-188, and the corrosion coupon data from Tank WM-182. This revision to the July report contains the additional information that fulfills the November 15, 1999, requirements.

The video of the interior of Tank WM-188 showed that the wall surfaces and welds are in good condition with no visual evidence of localized corrosion. The coupons retrieved from Tank WM-182 showed that the tank has experienced light, uniform corrosion as expected. There was no evidence of significant localized corrosion or accelerated uniform corrosion.

The conclusion of the report is that the estimated life of the tank system is far greater than the time required (per the Settlement Agreement and NONCO) for emptying the tanks as well as for the planned closing of the tanks.

ACNOWLEDGEMENT

Ronald E. Mizia, INEEL Fellow Engineer and materials expert, performed an essential role in the publishing of this document. He was originally commissioned to perform an independent, expert, quality check of the report to assure it was technically defensible. He not only performed this essential function, but his suggestions and additional work also added greatly to the readability, clarity, and completeness of the document. The authors thank him for this service.

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ACRONYMS and ABBREVIATIONS

AE	Architect Engineer
AISI	American Iron and Steel Institute
API	American Petroleum Institute
APS	Atmospheric Protection System
ASTM	American Society for Testing and Materials
CBI	Chicago Bridge and Iron Company
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOE	Department of Energy
DR	Density Recorder
DBE	Design Basis Earthquake
ECA	Environmental Controlled Area
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ENICO	Exxon Nuclear Idaho Company reports identifier
FY	Fiscal year (October 1 through September 30)
HLLW	High Level Liquid Waste
HLLWE	High Level Liquid Waste Evaporator
HLW	High-level waste
ICP	Allied Chemical Corporation reports identifier
ICPP	Idaho Chemical Processing Plant
ID	Idaho Operations Office (DOE)
IDO	Idaho Operation Office reports identifier
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
ITC	International Technology Corporation
Kr-85	Krypton isotope 85
LDUA	Light Duty Utility Arm
LR	Level Recorder
mil	0.001 inch
mpy	mils per year
NDE EE	Nondestructive Examination End Effector
NON	Notice of Noncompliance
NONCO	Notice of Noncompliance Consent Order
NWCF	New Waste Calcining Facility
PC	Performance Category
PEW	Process Equipment Waste
PR	Pressure Recorder
PUA	AE piping specification identifier
PVR	Pressure/Vacuum Relief
PWA	AE piping specification identifier
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision

SBW	Sodium Bearing Waste
SCC	Stress Corrosion Cracking
SNF	Spent Nuclear Fuel
SS	Stainless Steel
UDS	Undissolved Solids
VOG	Vessel Off Gas
WC	AE designation for WCF cell area
WCF	Waste Calcining Facility
WINCO	Westinghouse Idaho Nuclear Company reports identifier
WL	AE area designator for radioactive liquid waste management
WM	AE area designator for highly radioactive liquid waste management
WRN	AE piping specification identifier
WRV	AE piping specification valve identifier

Status and Estimated Life of the 300,000-Gallon INTEC Tanks

1. INTRODUCTION

On April 19, 1999, the State of Idaho, the Department of Energy (DOE), and the U. S. Environmental Protection Agency (EPA) approved the Third Modification to the Notice of Noncompliance Consent Order. Section III.2.d of that modification states:

> "By July 31, 1999, DOE shall submit to the Department a report detailing the past studies, current status and estimated life of the eleven 300,000-gallon INTEC tanks, and ancillary equipment, based upon existing data. By November 15, 1999, DOE shall submit an amendment to the report to the Department. The amendment shall include a detailed long-term plan and schedule for inspection and corrosion coupon evaluation for the tanks, a corrosion evaluation of the visual data from the light duty utility arm entry into Tank WM-188, and the corrosion coupon data from Tank WM-182."

The first report called for was issued on July 28, 1999. This revision to the July report provides the additional information to fulfill the November 15, 1999 requirement.

2. BACKGROUND

2.1 Historical

Irradiated nuclear fuel has been stored and reprocessed at the Idaho National Engineering and Environmental Laboratory (INEEL) since 1953 using facilities located at the Idaho Nuclear Technology and Engineering Center (INTEC) (formerly the Idaho Chemical Processing Plant or ICPP). The overall mission of INTEC is depicted in Figure 1. Historically, spent nuclear fuel (SNF) was brought to INTEC from a variety of reactors throughout the world and was stored either underwater in pools or in dry storage facilities for an interim period. Some of the SNF was chemically reprocessed to recover uranium, lanthanum, neptunium, and krypton for the Department of Energy and its predecessor organizations. This reprocessing produced mixed[1] liquid waste, which was stored in the Tank Farm. Since 1963, most of this liquid waste has been removed from the Tank Farm and solidified using a process called calcination. Calcination evaporates the water and other volatiles from the liquid waste and converts the remaining materials to dry granular solids. The calcine solids from this process are stored in specially designed stainless steel (SS) storage bins contained in concrete vaults.

[1] Mixed is a regulatory term for waste that contains both radioactive and hazardous constituents. The hazardous constituents are defined in the Resource Conservation and Recovery Act (RCRA). Both listed and characteristic components, as defined by RCRA, are contained in the INTEC waste.

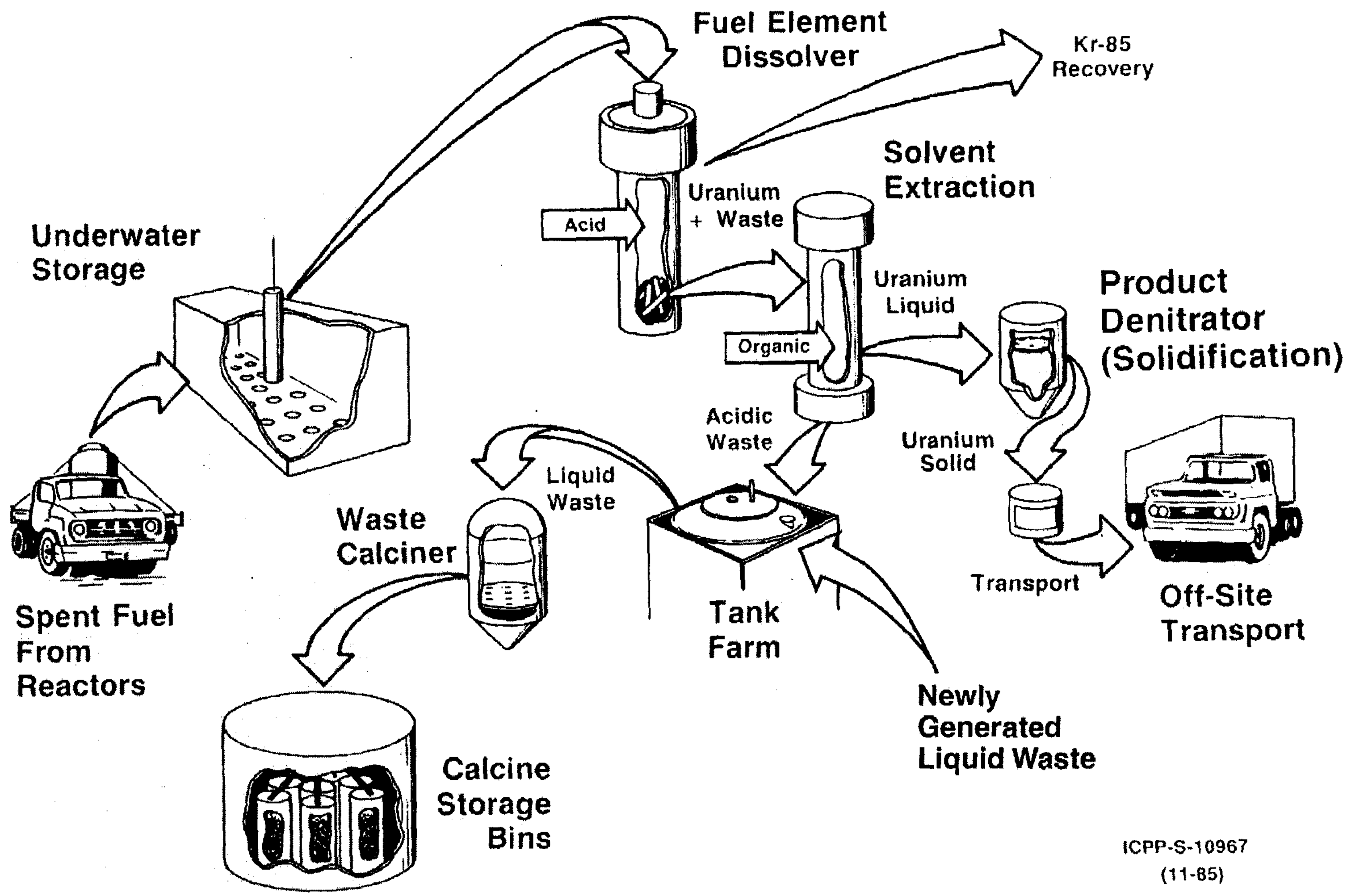

Figure 1. INTEC Process Flow

A variety of SNF types was processed at INTEC (Figure 2). Two types of liquid waste have been stored; they are high level waste (HLW) and sodium bearing waste (SBW)[2]. The HLW was generated as a direct result of reprocessing SNF. The composition of the HLW was dependent on the fuel type being processed, with aluminum, zirconium, and Fluorinel producing the greatest volumes of waste. The SBW was generated from incidental activities, such as decontamination, associated with operation of the INTEC. The name "Sodium Bearing Waste" is in recognition of the waste's high concentration of sodium ion. The sodium resulted from processing and decontamination activities that made extensive use of sodium-based chemicals such as sodium hydroxide and sodium carbonate. Although the liquid SBW is stored and managed in essentially the same manner as the HLW, it is actually a mixed transuranic waste.

From 1953 to 1992, SNF was routinely reprocessed and the wastes (both HLW and SBW) were stored in Tank Farm tanks. From 1963 to 1981, the wastes were routinely calcined in the Waste Calcining Facility (WCF) and from 1982 to the present, the wastes were calcined in the New Waste Calcining Facility (NWCF). In April 1992, DOE announced that spent fuel would no longer be reprocessed and called for a shutdown of the reprocessing facilities at INTEC. Since that time, no more HLW has been (or is planned to be) generated from SNF reprocessing, but SBW generation continues (and will continue at a reduced rate) as a result of SNF storage, waste management, off-gas cleanup, and decontamination and decommissioning of unused facilities. From 1992 to 1998, the Calciner continued to process the remaining HLW liquid. On February 20, 1998, the last of the HLW that was stored in Tank WM-188 was calcined. Except for the WM-188 heel[3], for practical purposes only SBW remains in the Tank Farm. Calcination of SBW has continued since that time and the total Tank Farm volume has now been reduced to approximately 1.3 million gallons of SBW (Figure 3). This is the lowest volume of waste the Tank Farm has stored since 1959.

2.2 Tank Farm Operations

The operating conditions and performance of the INTEC waste tanks have been continuously monitored on a daily basis since their installation. The liquid levels inside the tanks are continuously monitored to assure any potential leak is rapidly detected. The tank vault sumps are also continuously monitored for liquid buildup.

Table 1 shows typical chemical compositions for the high level liquid waste (HLLW) and SBW that has been stored in the Tank Farm. The zirconium, Fluorinel, and aluminum reprocessing wastes were readily calcined due to their high concentration of dissolved metals such as aluminum and zirconium. SBW, which is nearly 100 times higher in sodium and potassium content, cannot be calcined directly because the sodium and potassium form compounds that melt at calcination and bin storage temperatures. Melting of the calcine causes the calcine to

[2] Sodium-bearing waste has been termed intermediate waste in the past as shown in Figure 2. Since essentially all of the SBW is concentrated by the Process Equipment Waste (PEW) Evaporator prior to storage in the Tank Farm, it is sometimes called PEW Evaporator bottoms.

[3] The HLLW heels, which existed in some of the other tanks, have been flushed using SBW.

agglomerate in the fluidized bed and storage bins; this would shut down the calcination process and possibly prevent retrieval from the storage bins and further processing to a final waste form. In the past, the Calciner has processed SBW by blending it with fuel reprocessing wastes (approximately three volumes of reprocessing waste to each volume of SBW).

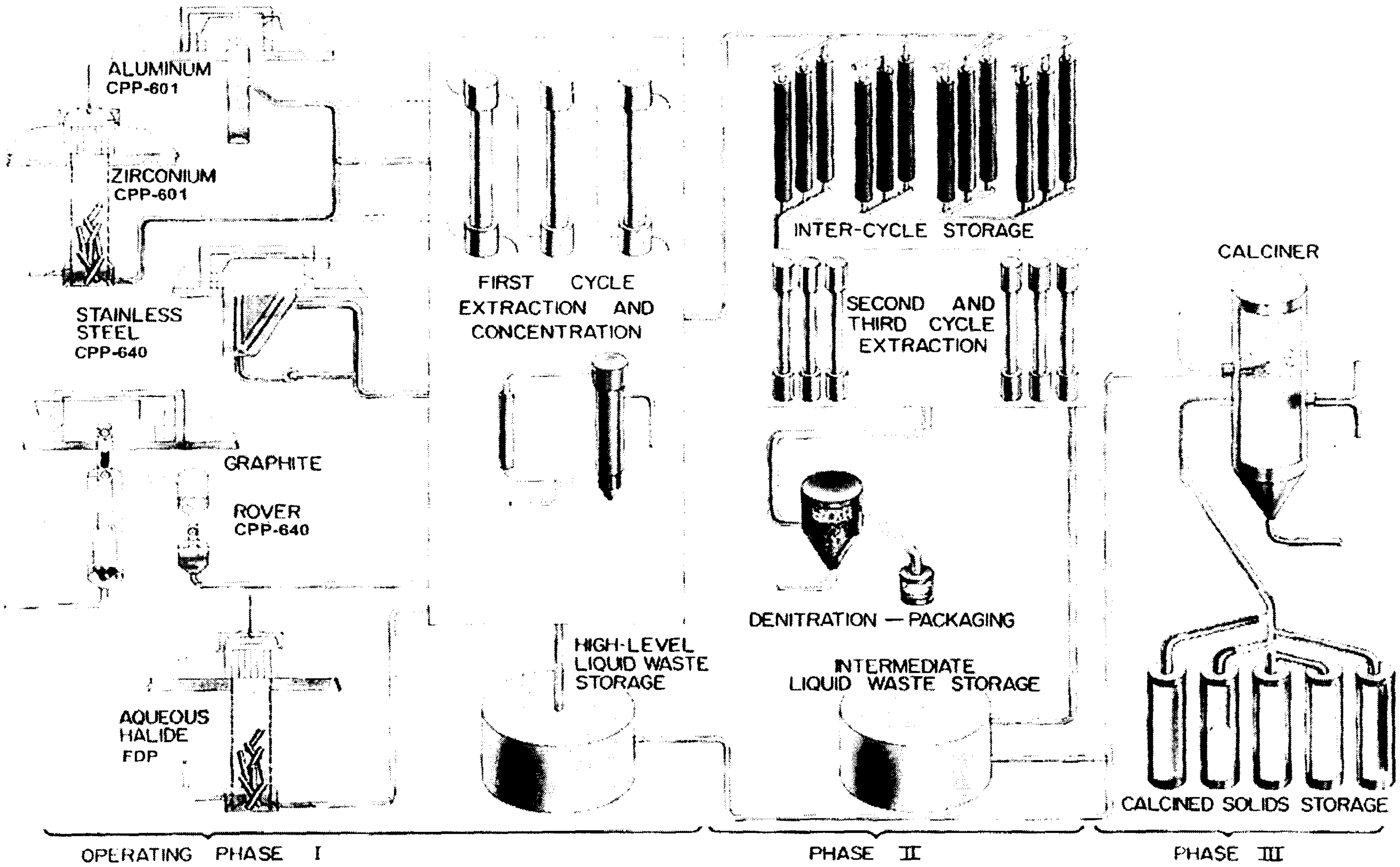

Figure 2. Fuel Reprocessing at Idaho Nuclear Technology and Engineering Center

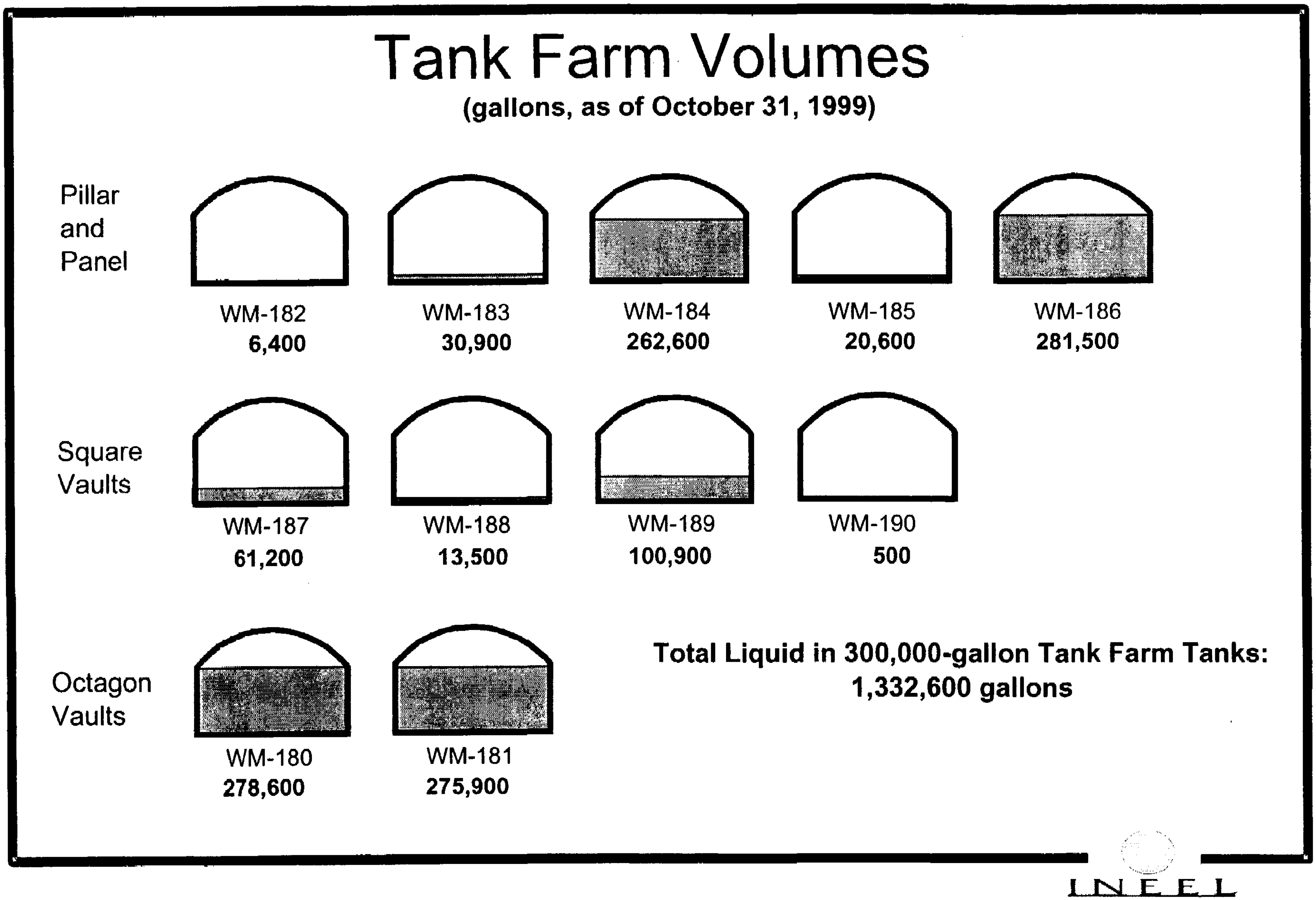

Figure 3. Tank Farm Status

Table 1. Typical Liquid Waste Chemical Compositions.

Major Species	Units	Zirconium	Fluorinel	Sodium Bearing	Aluminum
Acid (H^+)	Molar	1.4	1.5	1.28	0.81
Aluminum (Al)	Molar	0.68	0.43	0.57	1.5
Zirconium (Zr)	Molar	0.41	0.31		
Boron (B)	Molar	0.19	0.15	0.017	
Cadmium (Cd)	Molar		0.05	0.001	
Sodium (Na)	Molar	0.017	0.02	1.50	0.06
Potassium (K)	Molar	0.003		0.17	
Chromium (Cr)	Molar	0.015	0.015		
Iron (Fe)	Molar	0.007	0.005	0.002	0.01
Tin (Sn)	Molar	0.005	0.004		
Mercury (Hg)	Molar			0.0013	0.02
Fluoride (F)	Molar	3.20	2.10	0.04	
Chloride (Cl)	mg/L		50	1000	
Nitrate (NO_3)	Molar	2.30	1.90	4.50	5.40
Sulfate (SO_4)	Molar		0.035	0.043	
Uranium (U)	mg/L	1.30	6.5	66.4	
Undissolved Solids	g/L	2.0	2.0	2.4	
Liquid Density	g/mL	1.20	1.15	1.25	1.28

The blending diluted the sodium and potassium, thus permitting successful calcination. Since the INTEC is no longer reprocessing spent fuel, no more reprocessing waste will be generated. Tank WM-188 contained the last of the reprocessing waste and when it was emptied in February 1998, efficient blending to dilute the sodium and potassium in the Calciner feed was no longer possible. Calcination of the remaining Tank Farm wastes will proceed more slowly than in the past because the SBW will have to be blended with non-radioactive materials, such as aluminum nitrate, for successful calcination.

The current estimated chemical and radionuclide compositions of the Tank Farm wastes, based on historical processing and some sample analyses, are provided in Appendix A. The liquid waste stored in the Tank Farm has been maintained in the acidic (WM-180 was 0.08 N base for the initial tank filling) condition and, because of this, gross solids precipitation, as occurs in HLLW tanks at other DOE sites, has not happened at INTEC and the waste is a clear (although colored) liquid. A small amount (perhaps one inch) of solids is expected to be accumulated on the bottom of each tank due to undissolved process solids, a small amount of accumulated dirt, and minor solids precipitation. The 1999 video inspection of the Tank WM-188 heel shows what appears to be a film-like deposit with suspended solids just below the liquid surface. This phenomenon has not been observed in the other tank inspections. The possible composition of this material and its significance have not been determined. Further evaluation of the video and the chemistry existing in this heel will be done. These liquid wastes have been routinely transferred from tanks to the calcining facility with no significant problems; this same success in transferring liquid wastes is expected for processing the remaining Tank Farm wastes. Since the liquid wastes are chemically stable and contain very few precipitated solids, sampling and analysis of the liquid are relatively easy when compared to sampling mixtures of solids, sludge, and liquid which commonly exist in waste tanks at the other DOE sites; however, the sampling and analyses are still time consuming and expensive. All of the liquid wastes have been sampled and the general chemical and radionuclide compositions have been determined. Obtaining the detailed chemical characterizations that are required by the Resource Conservation and Recovery Act (RCRA) is in progress and will take several years to complete. Ultimately, the Tank Farm wastes and calcine must be removed from their storage locations and converted to forms suitable for permanent disposal. The process to convert the waste to those forms has not yet been determined. An Environmental Impact Statement (EIS) and Record of Decision (ROD) will be issued in FY-2000, which will select a preferred alternative to process these waste forms.

2.3 Waste Generation

Historically, the major waste stream stored in the Tank Farm was from spent nuclear fuel reprocessing. When reprocessing was terminated in 1992, a common misconception, based on questions asked during various HLW Program presentations, was that radioactive liquid waste production would cease and the Tank Farm could be rapidly emptied. In actuality, fuel reprocessing was only one of several operations at the INTEC that produced waste. Waste continues to be produced by plant operations such as, fuel storage, sample analyses, off-gas cleanup, Tank Farm and other facilities' sumps, the filter leach process, equipment and facility decontamination, RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) well sampling, facility deactivation, and RCRA closure activities. In addition, the INTEC can receive liquid waste from other areas within the INEEL with DOE-

Idaho Operations Office (ID) approval. However, even though liquid waste continues to be produced, since fuel is not being reprocessed, significant amounts of additional radionuclides or heavy metals (such as mercury and cadmium) are not being introduced into the INTEC liquid waste management system. Therefore, the radionuclide inventory in the liquid and the associated radiological risk are continually decreasing due to radioactive decay and conversion of the radioactive liquids to calcine solids. The DOE has challenged the HLW Program to significantly reduce liquid waste generation that goes to the Tank Farm and has created a 5-year waste minimization incentive. The HLW Program has developed plans to achieve the desired reductions and has successfully met these goals.

2.4 Regulatory Issues and Status

The INTEC Tank Farm currently operates under interim status with a RCRA Part A permit for storage of hazardous wastes and a consent order, which is described below. There are no plans to submit a Part B application because it is not clear that the tank systems could be upgraded to meet the required standards.

Due to aging of the tanks and support facilities and more stringent requirements in the areas of secondary containment and seismic stability, a project was initiated in 1989 to replace the INTEC Tank Farm. The Notice of Noncompliance (NON), issued by the EPA on January 28, 1990, supported the DOE decision to construct replacement tanks. The NON contended that the eleven tanks in the INTEC Tank Farm and much of their associated valves and piping were not in compliance with secondary containment requirements for acidic waste. Specifically, the concrete vaults for the tanks are unlined and if a tank leaked, the acidic waste would react with the concrete and could eventually dissolve a hole through the vault wall or floor. The pillar and panel construction of some of the tank vaults is not as structurally robust as the monolithic designs and will not meet current DOE (as explained in Section 4.4 of this report) seismic design standards.

The NON Consent Order (NONCO), signed April 3, 1992, outlined a compliance schedule for the completion of several tasks that would ultimately result in the required permanent cessation of use of the five pillar and panel tank vaults containing Tanks WM-182 through WM-186 on or before March 31, 2009. Cease use for the remaining six vaults containing Tanks WM-180, WM-181, and WM-187 through WM-190 would occur on or before June 30, 2015, among other provisions. The Idaho Settlement Agreement, signed October 17, 1995, requires all SBW to be calcined by December 31, 2012. The Second Modification to the NONCO, signed August 18, 1998, accelerated cease use of the pillar and panel vaulted tanks to June 30, 2003 and cease use of the remaining six tanks to December 31, 2012. The Third Modification to the NONCO, signed April 19, 1999, left existing Tank Farm milestones in place. However, it required submission of a report and an amendment to the report that detailed the past studies, current status, and estimated life of the eleven 300,000-gallon INTEC tanks and ancillary equipment.

2.5 Corrosion Mechanisms

The purpose of this section is to show examples of the types of corrosion that are possible in the waste tanks. However, the waste storage environment is controlled (i.e., tank construction, waste composition, storage temperature) to assure metal passivity is maintained and localized corrosion is avoided. These actions prevent all but uniform corrosion. The photographs in this section can be compared to the photographs of the internals of Tank WM-188 in Section 4.7 and the photographs of coupons taken from Tank WM-182 in Section 4.8 to assure that localized corrosion is not occurring in these tanks.

Stainless steels are iron-base alloys containing 10.5% or more chromium. They have been used for many years for applications requiring corrosion resistance in the nuclear, chemical, and petrochemical industries. There are over 50 varieties of stainless steels which can be placed in three general classifications for identification: 1) Metallurgical Structure, 2) American Iron and Steel Institute (AISI) Numbering System: namely 200, 300, and 400 Series numbers, and 3) The Unified Numbering System. (Reference 1)

The metallurgical structure of the stainless alloys breaks down into the following categories: 1) Austenitic (200 and 300 series) contain chromium and nickel as alloying additions, are not hardenable by heat treatment, and are used for corrosion and heat resistance. 2) Martensitic (400 series) contain chromium and are hardenable by heat treatment. They have moderate corrosion resistance and are used where high strength and hardness are required in applications such as bearings, cutlery, compressors and turbines. 3) Ferritic (400 series) contain chromium and are not hardenable by heat treatment. They have moderate strength and corrosion resistance and are used in applications such as architecture, automobile trim and transportation. 4) Precipitation hardening (controlled transformation) alloys can be hardened by an aging heat treatment and are used where a combination of good corrosion resistance and mechanical properties are needed. They find application in the aircraft and aerospace industries. 5) Duplex alloys have a metallurgical structure that is a combination of the austenitic and ferritic structures and are used in the chemical process industries where excellent resistance to chloride induced pitting and stress corrosion cracking is needed. (Reference 1)

Stainless steels derive their corrosion resistance from a thin, invisible, surface layer of chromium oxide that is formed during a reaction between the metal and the oxygen present in the ambient air environment or aerated solutions. If mechanically damaged, this layer can spontaneously reform. This thin layer of oxide, which is called the passive layer, is responsible for the improved corrosion resistance of the material as compared to other iron based alloys such as carbon steel. Since the corrosion resistance is dependent on the properties of this oxide, the stainless steels are not inert to most environments in the way that a noble metal like platinum is. The passive film may be damaged or broken down at a localized site.

Corrosion Definitions

The following corrosion definitions are included from the American Society for Testing and Materials (ASTM) G15-99 (Reference 2). They are the terms used to define various aspects of materials degradation due to corrosion.

Corrosion - the chemical or electrochemical reaction between a material, usually a metal, and its environment, that produces a deterioration of the material and its properties.

Corrosion rate - the amount of corrosion occurring in unit time (for example, mass change per unit area per unit time; penetration per unit time).

Crevice corrosion – localized corrosion of a metal surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment, because of close proximity between the metal and surface of another material.

Galvanic Corrosion – accelerated corrosion of a metal because of an electrical contact with a more noble metal or nonmetallic conductor in a corrosive electrolyte.

Intergranular corrosion – preferential corrosion at or adjacent to the grain boundaries of a metal or alloy.

Localized corrosion – corrosion at discrete sites, for example, pitting, crevice corrosion, and stress corrosion cracking.

Pitting – corrosion of a metal surface, confined to a point or small area, that takes the form of cavities.

Stress-corrosion cracking – a cracking process that requires the simultaneous action of a corrodent and sustained tensile stress. (This excludes corrosion-reduced sections that fail by fast fracture. It also excludes intercrystalline or transcrystalline corrosion which can disintegrate an alloy without either applied or residual stress).

Uniform corrosion – corrosion that proceeds at about the same rate over a metal surface. Also known as "general" corrosion.

Waste Tank Materials

The 300,000-gallon INTEC waste tanks are fabricated out of 304L or 347 stainless steel. Both of these materials are commonly used for corrosion applications. The low carbon (0.03% max) in 304L increases the resistance of the material to intergranular corrosion in the as-welded condition. For 347 the carbon (0.08 % max) is preferentially combined with columbium and distributed uniformly through the metal matrix to control intergranular corrosion.

Review of Possible Corrosion Failure Modes for 304L or 347 Stainless Steels

The following photographs and discussions are included to illustrate the types of corrosion that could occur in these waste tanks. The pictures are from laboratory corrosion testing and metallurgical analysis that has been performed on failed components. Although some of the examples shown are not 304L or 347 stainless steel, the corrosion mechanisms and coupon appearance accurately represent what would occur in 304L or 347.

Figure 4 is a corrosion coupon made of 304L stainless steel that was prepared for an underground corrosion test that is in progress at the INEEL. The coupon has been ground to a 120 grit surface finish. This coupon has a much better initial surface finish than the commercial quality stainless steel plate used in the tank fabrication. It is included here to serve for comparison purposes for the coupons shown in Figures 5, 6, 7, 9, and 10.

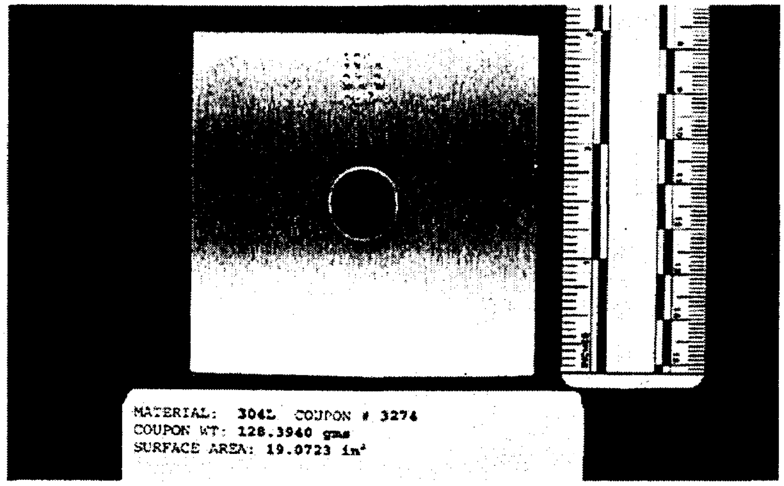

Figure 4. 304L Corrosion Test Coupon, Prepared per the Requirements of ASTM G 1 (Reference 3)

Uniform or General Corrosion

Figure 5 shows three coupons of Hastelloy C-22 (Nickel-Chromium-Molybdenum alloy) material that have undergone corrosion testing in a standard corrosion test (Reference 4, ASTM G 28, Method A) for nickel based alloys. The samples have undergone uniform corrosion with no localized pitting or cracking and retain much of their original metallic luster. The average corrosion rate was 28 mils per year. These coupons were tested in the solution annealed condition.

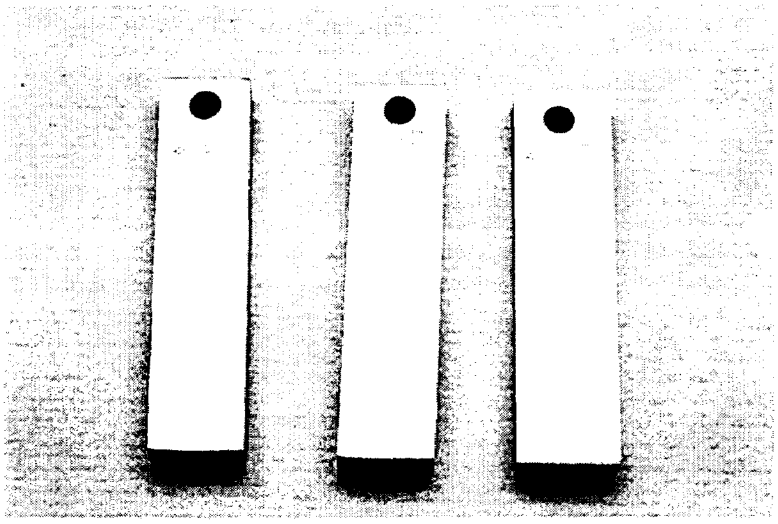

Figure 5. Hastelloy C-22, Uniform Corrosion, Tested per ASTM G28-97, Method A

Intergranular Corrosion

Intergranular corrosion in stainless steels and chromium containing nickel based alloys results from the precipitation of chromium carbide and possibly other non-metallic, secondary phases at the metallic grain boundaries. These phases can occur if the metal is heated into and slowly cooled through a temperature range of 500 to 850°C (stainless steels). The commonly accepted explanation is that the carbon in the vicinity of the grain boundaries diffuses to the grain boundaries to produce the chromium carbide. The formation of these phases can cause variation in chemistry in the area of the grain boundary, which in turn can cause variations in corrosion resistance.

Intergranular corrosion of stainless steels can occur if they are held at a temperature in the sensitizing range for a sufficient length of time. This can occur in the base metal of a fabrication near a weld where the metal slowly cools through this temperature range.

Figure 6 shows intergranular corrosion damage of Hastelloy C-22 corrosion coupons that were heat treated at 649°C for 1072.25 hours and tested in ASTM G 28, Method A. The surface is extremely rough and the measured corrosion rate was extremely high at 1307 mils per year. The effect of holding the metal at a temperature in the sensitizing range for a sufficient time can be seen by comparing these coupons with the coupons in Figure 5.

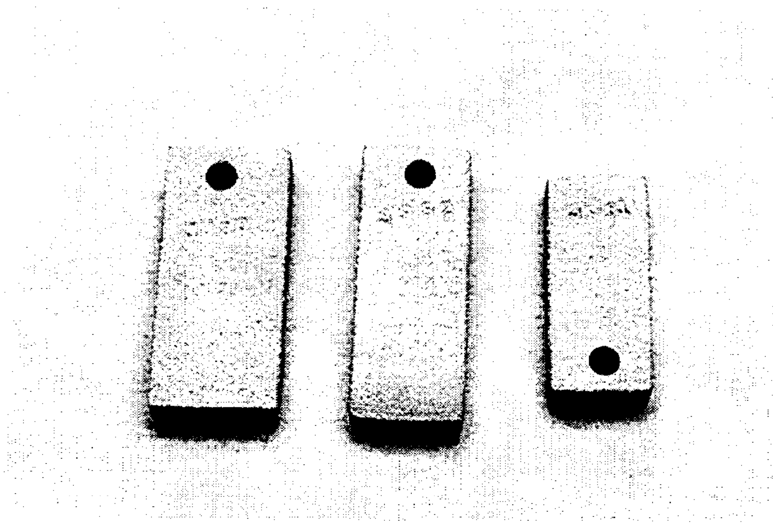

Figure 6. Hastelloy C-22, Intergranular Corrosion

Figure 7 shows the intergranular corrosion of a Nickel-Chromium-Molybdenum alloy (Allcor) in the weld heat affected zone. The severe localized corrosion around the metal grains is evident.

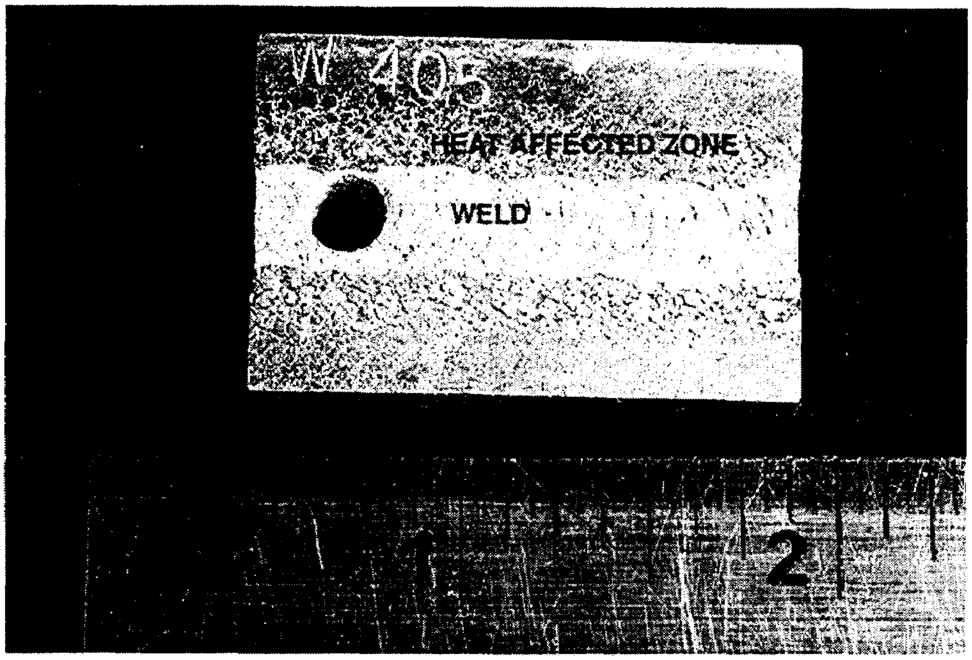

Figure 7. Intergranular Corrosion in the Weld Heat Affected Zone

In a welded component, intergranular corrosion can cause an accelerated loss of wall thickness in the weld heat affected zone as shown in Figure 8. The material here was 304 stainless steel that has a higher allowable carbon content (0.08%). The weld heat affected zone of the base metal is in the center of the photograph. The weld metal is on the right side of the photograph. The intergranular corrosion allowed leakage through the stainless steel wall.

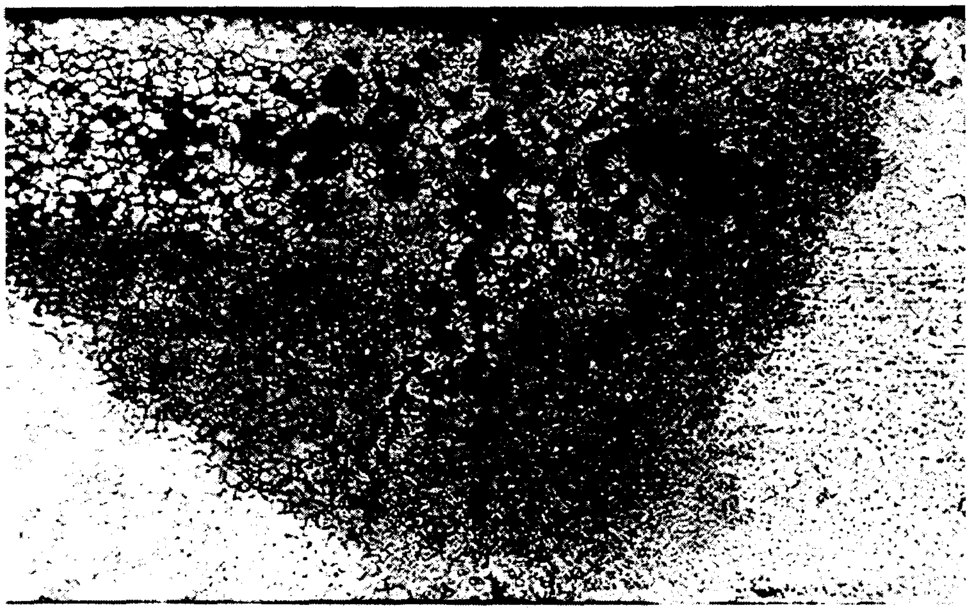

Figure 8. Cross Sectional View, Intergranular Corrosion in the Weld Heat Affected Zone, 304 SS

Pitting

Pitting is another form of localized corrosion that can affect stainless steels and other alloys that rely on a passive film for corrosion protection. It is characterized by damage at discrete sites on the surface. The pits visible on the surface may have larger areas of internal damage. The local breakdown of the passive layer will be facilitated by chloride ions at metallurgical imperfections. These imperfections may be non-metallic inclusions, localized changes in metallurgical structure from heating cooling cycles (surface grinding) and surface deposits. Figure 9 shows three Hastelloy C-22 coupons that were tested per the requirements of ASTM G 28, Method B (Reference 5). The coupons show massive pitting that would obviously reduce the wall thickness.

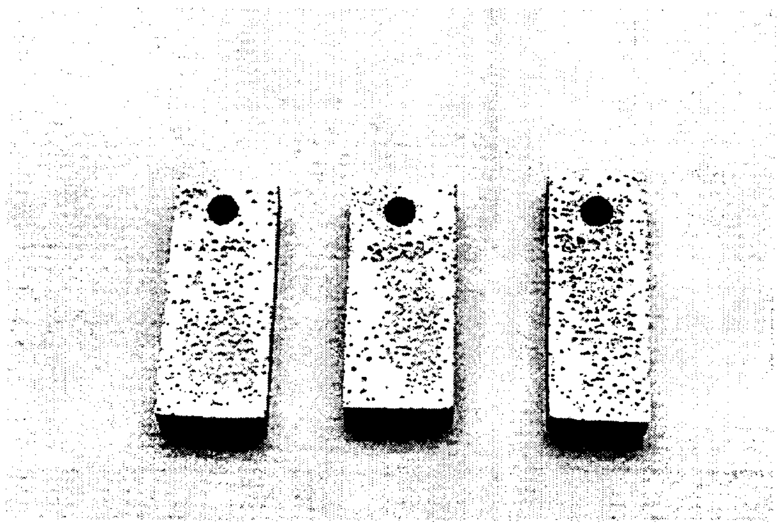

Figure 9. Hastelloy C-22, Pitting, Tested in ASTM G28, Method B

Figure 10 shows a 304L stainless steel coupon that was exposed to a ferric chloride solution. The pitting extends through the section thickness.

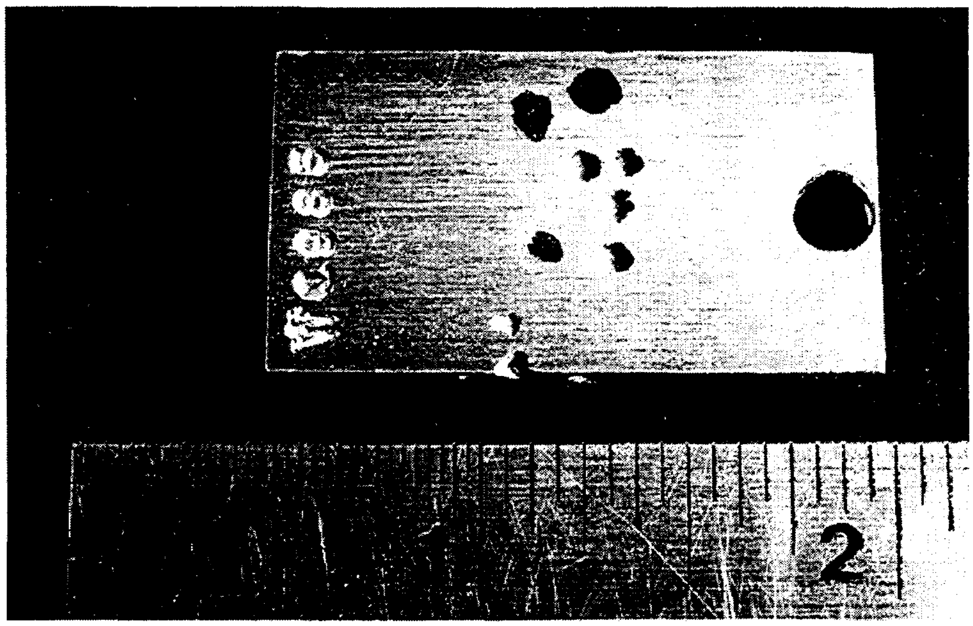

Figure 10. Pitting of 304L Coupon Exposed to Ferric Chloride

Stress Corrosion Cracking

Stress Corrosion Cracking (SCC) occurs where a normally ductile metal like stainless steel fails in a brittle manner by cracking. The cracks can extend through the wall thickness of a tank and cause leakage. The necessary conditions for this to occur are a susceptible material, tensile stress, minimum threshold temperature, and a particular corrosive environment. These conditions can be met for stainless steels where the corrosive environment contains chloride ion. The residual stress tensile stresses are induced by welding and the operating temperature is above an approximate minimum threshold temperature of 60°C.

Figure 11 shows the top head area of a heat exchanger made of 304L stainless steel that failed after approximately 10 days of service. The system was inadvertently filled with raw water (20 ppm chloride ion) instead of demineralized water. The section was cut out at the weld which was at the top of the picture. Figure 12 shows a magnified view near the outlet nozzle shown near the top of Figure 11. It can be seen that there is heavy cracking in the base metal near this nozzle and the top closure weld.

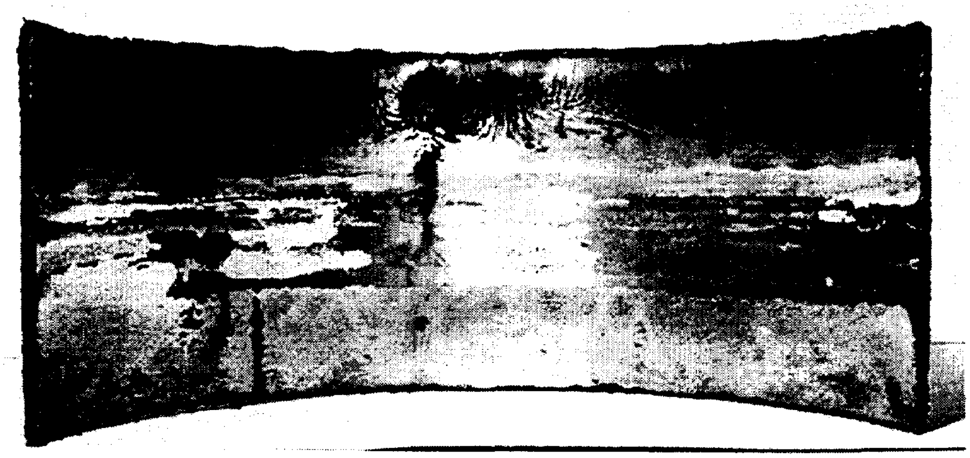

Figure 11. Stress Corrosion Cracking of a 304L Stainless Steel Heat Exchanger

Figure 12. Higher Magnification View of Figure 11

Figure 13 shows the external wall of a 304L stainless steel chemical storage tank that failed from chloride induced stress corrosion cracking. Figure 14 shows one of the corrosion pits where the stress corrosion cracks grew from the pits.

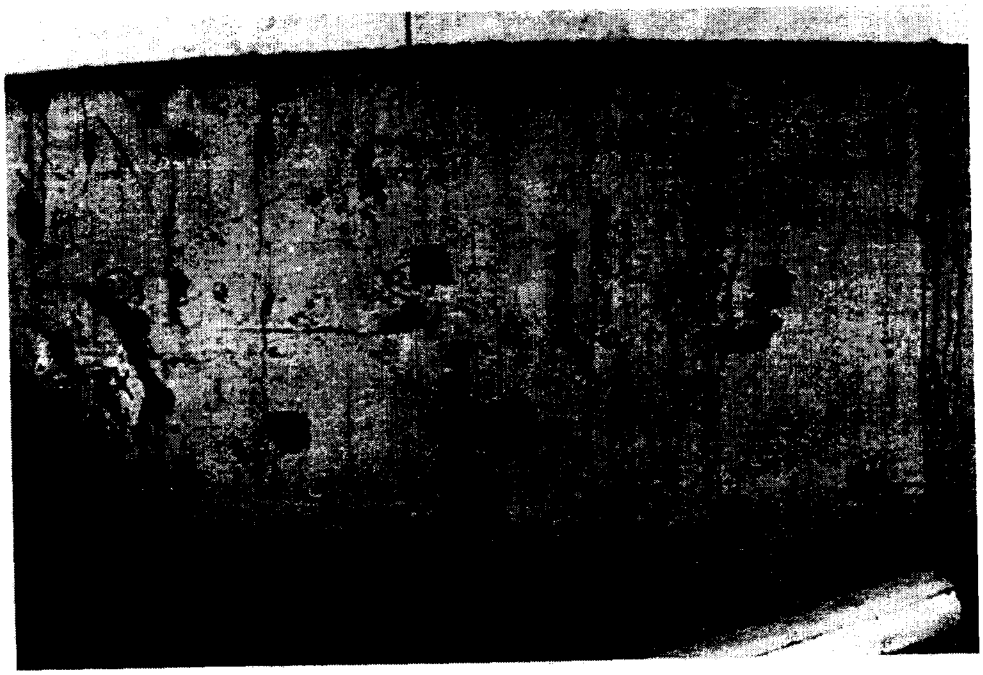

Figure 13. Cracking on External Surface of 347 SS Tank Exposed to Magnesium Chloride

Figure 14. Enlarged View of Localized Corrosion Area of Figure 13

Figure 15 is a view of one of the areas of localized pitting/cracking that was cut out of the metal wall and prepared for microscopy. The photograph shows a magnified view (37.5X) of the wall cross section.

Figure 15. Enlarged View (37.5X) of a Crack

Crevice Corrosion

Crevice corrosion can occur in stainless steels where there is metal-to-metal contact or metal-to-non-metal contact where there is shielding of a surface from the corrosive solution. To illustrate this, examples of crevice corrosion observed in a corrosion test program are provided. Figure 16 shows the corrosion coupon test assembly where the stainless steel sample has a non-metallic washer with crevices in it fastened on the coupon surface. This testing is based on ASTM G 78-95 (Reference 6). Figure 17 shows a stainless steel coupon that was exposed to a solution containing a high chloride level. The coupon shows localized damage from the effect of the crevice on the surface from the washer.

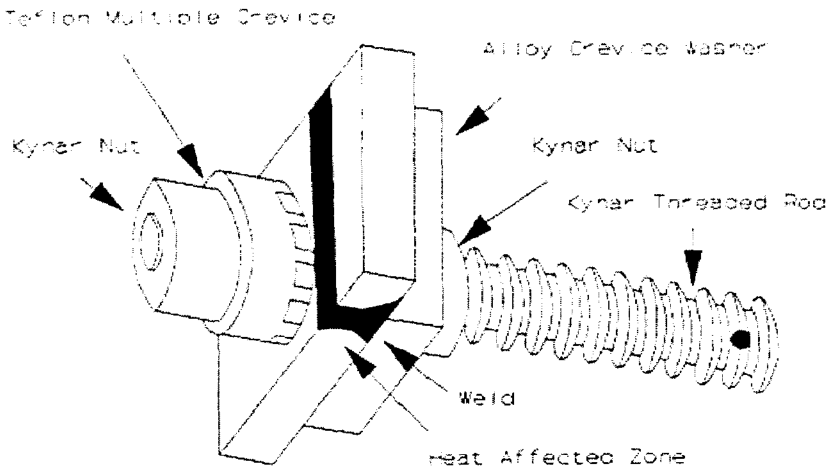

Figure 16. Crevice Corrosion Test Assembly

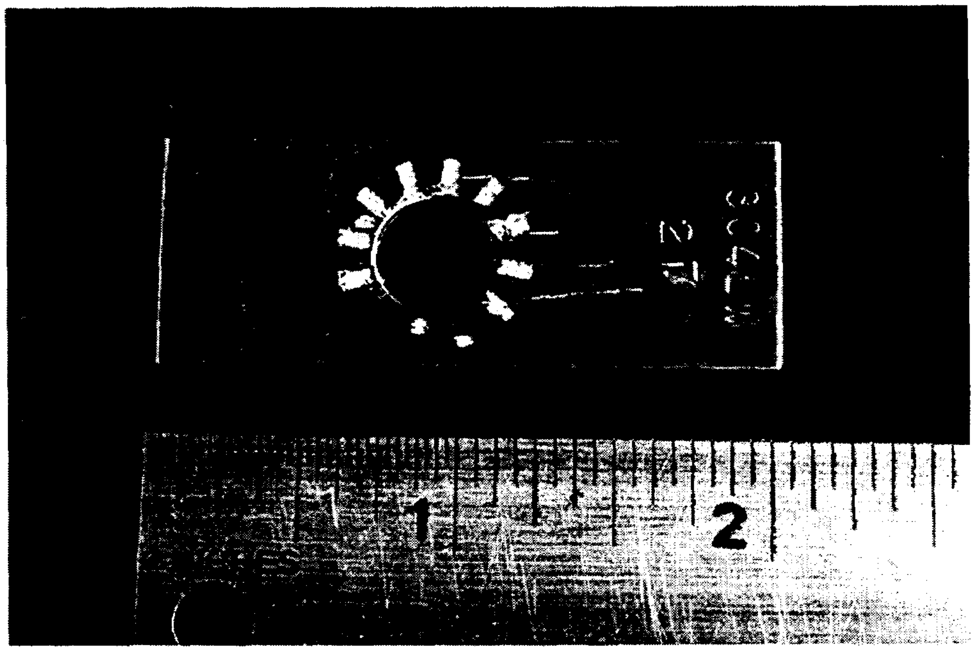

Figure 17. Crevice Corrosion, 304L Stainless Steel

Galvanic Corrosion

One additional type of corrosion that could occur in the waste tanks is galvanic corrosion between the base metal plates used for the tank wall and the weld metal. The result would normally be an accelerated corrosion of the weld metal where it would corrode at a faster rate than the tank wall material. This would be considered an unusual case, but could occur if the as-deposited weld metal chemistry would make it inferior in corrosion resistance to the base metal. An example of this is shown in Figure 18. The material is Inconel 690 (Nickel-Chromium-Iron) which was exposed to a boiling Nitric Acid-Hydrofluoric Acid solution.

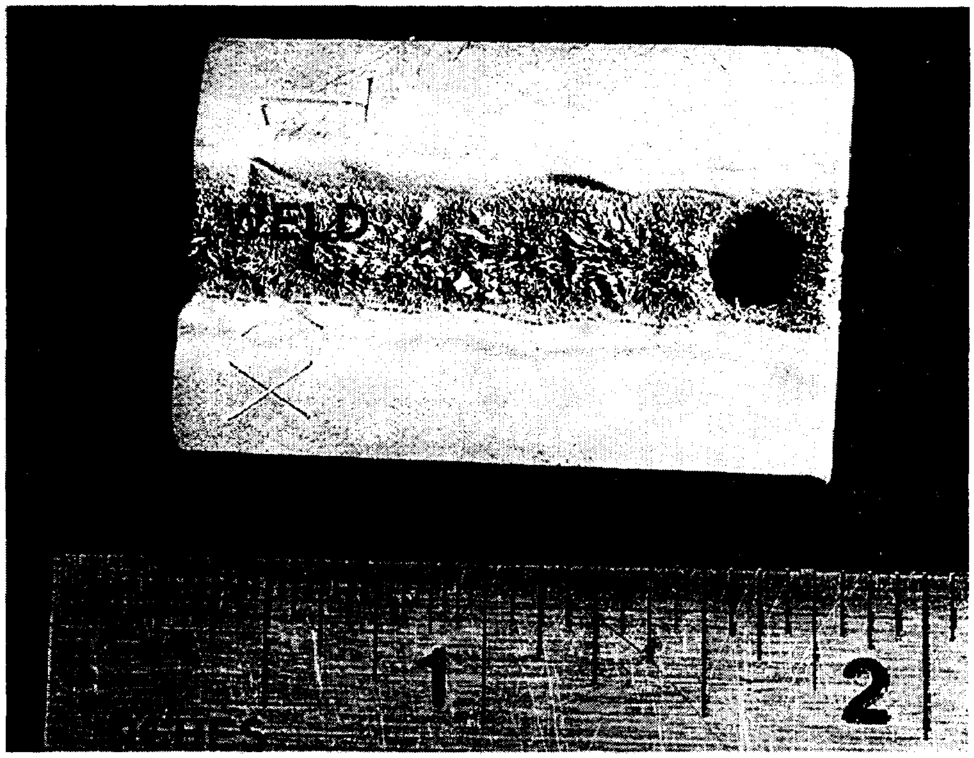

Figure 18. Galvanic Corrosion, Accelerated Weld Metal Corrosion of Inconel 690

Corrosion of Stainless Steels in High Level Waste Tank Environments

For long term performance of the tanks, when exposed to the waste solutions, uniform (rather than localized) corrosion would be desirable. If only uniform corrosion occurs, the loss of wall thickness can be adequately measured and remaining service life can be accurately predicted. The loss of wall thickness can be accounted for in the tank design with a corrosion allowance, which is added metal thickness over the wall thickness needed for mechanical design considerations. Localized corrosion such as pitting, crevice, or stress corrosion cracking will give an accelerated through-wall penetration rate and makes it difficult to predict remaining life.

3. TANK FARM FACILITY

3.1 General Description

The INTEC Tank Farm was constructed during the 1950s and 1960s and has been in continuous use since 1953. It consists of eleven vaulted 300,000-gallon underground tanks[4] in which the liquid wastes are stored (Figure 3). This facility is significantly different from other tank farms in the DOE complex in three respects. First, the tanks are constructed of stainless (not carbon) steels. Second, the wastes are stored in the acidic (not neutralized or alkaline) condition, thereby avoiding most of the technical problems, including corrosion and leaking tanks, that have occurred at other locations[5]. Third, the tanks have been repeatedly emptied and refilled over the years as liquid wastes were periodically withdrawn to be calcined and as additional new wastes were generated from continued fuel reprocessing.

The tanks are similar in design (Figure 19); each tank is a right cylinder 50 feet in diameter with a dome roof. The vertical sidewall is approximately 21 feet high. The material of construction is stainless steel ranging from 3/16 to 5/16 inch thick depending on the location in the tank. Stainless Steels are particularly well suited for service with acidic nitrate solutions. Stainless steels derive their corrosion resistance from a thin, invisible, surface layer of chromium oxide (Cr_2O_3) that is formed during a reaction between the metal and the oxygen present in the ambient environment or aerated solutions. If mechanically damaged, this layer can spontaneously reform. This thin layer of oxide, which is called the passive layer, is responsible for the improved corrosion resistance of the material. Since the corrosion resistance is dependent on the properties of this oxide, the stainless steels are not inert to most environments in the way that a noble metal like platinum is. The passive film may be damaged or broken down at a localized site. The passive layer is reinforced by the presence of oxidizing nitrate.

Eight of the tanks (WM-180, -182, -183, -185, -187, -188, -189, and -190) were built with cooling coils and were used for storing heat generating HLW. Three of the tanks (WM-181, -184, and -186) were built without cooling coils for storing non-HLW. Although the tanks are similar in design, the vault designs are significantly different. The INTEC began operations in the early 1950s with two liquid waste tanks (WM-180 and WM-181) which were constructed from 1951 to 1952. These two tanks are contained in vaults that are monolithic, reinforced concrete in an octagonal shape (Figure 20). As the scope of the INTEC operations increased, additional tanks were put into service. Tanks WM-182 through WM-186 were constructed from 1954 to 1957. These five tanks are also contained in octagonal vaults, but these are of pre-fabricated reinforced concrete pillar and panel construction (Figure 21). The four newest large liquid waste tanks, WM-187 through WM-190, were constructed from 1958 to 1964 and are housed in a four-sectioned, reinforced concrete vault (Figure 22). All of these tanks were

[4] The Tank Farm also contains other, smaller tanks, which are not addressed in this report.

[5] The DOE sites at Hanford and Savannah River neutralized their wastes and stored them in carbon steel tanks. However, after four decades of waste storage, the carbon steel tanks have developed leaks that have allowed liquid waste to escape to the environment.

designed and built to the standards at the time of construction and have served their designed function. The design of the vaults is important because the pillar and panel construction is not as robust as the monolithic construction and the unlined concrete in all of the vaults does not meet current RCRA secondary containment requirements because concrete is incompatible with the acidic waste. Although liquid waste leaks have occasionally occurred in associated valves and piping, no liquid waste leaks from the waste tanks have ever occurred. Although no tank has ever been known to leak, an empty spare tank has been maintained continuously available to immediately receive the contents of any other tank that might develop a leak. Table 2 provides construction details for the 300,000-gallon tanks and Figure 23 shows the Tank Farm and ancillary equipment interconnections and relative layout.

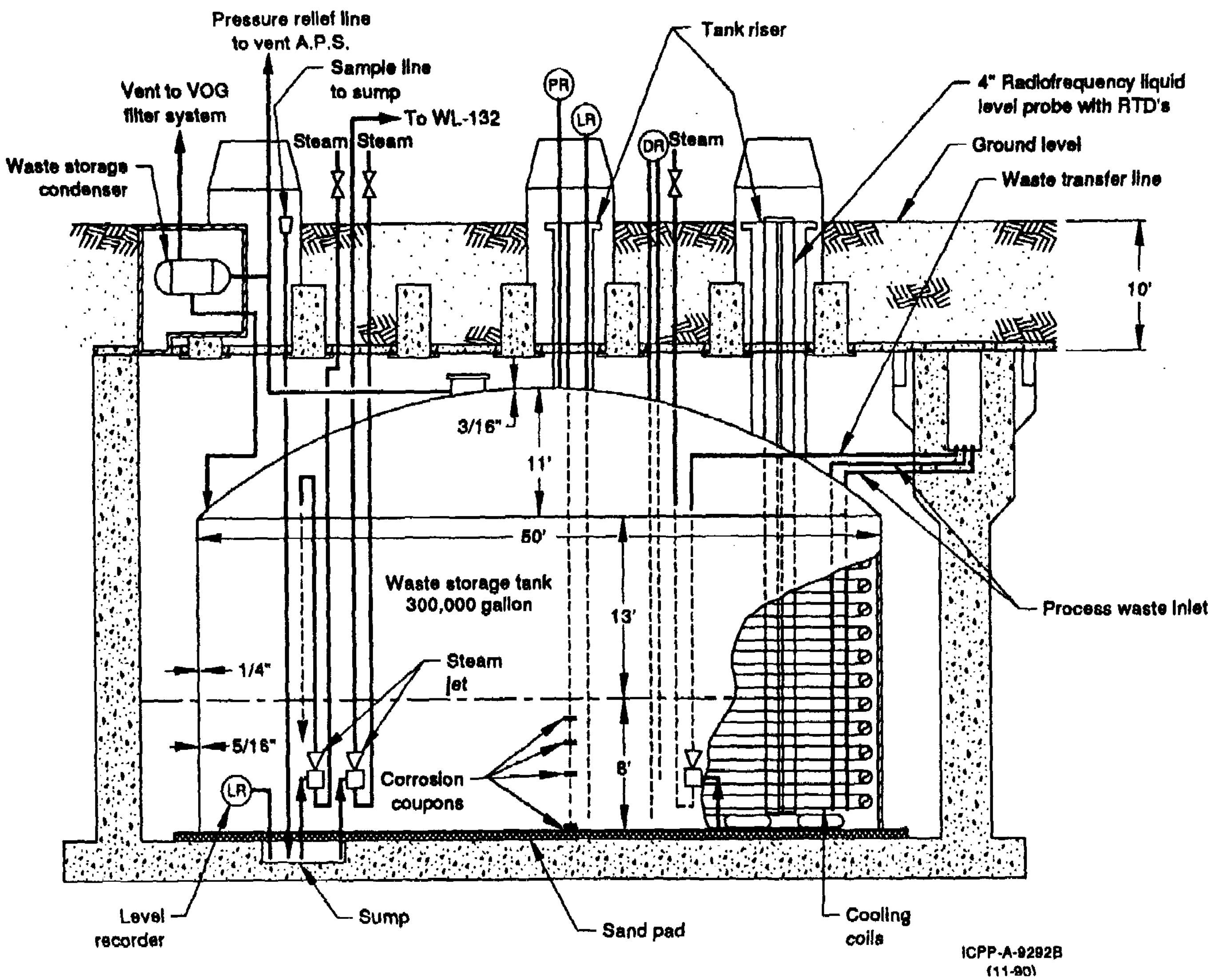

Figure 19. Typical First-Cycle Liquid Waste Tank at INTEC

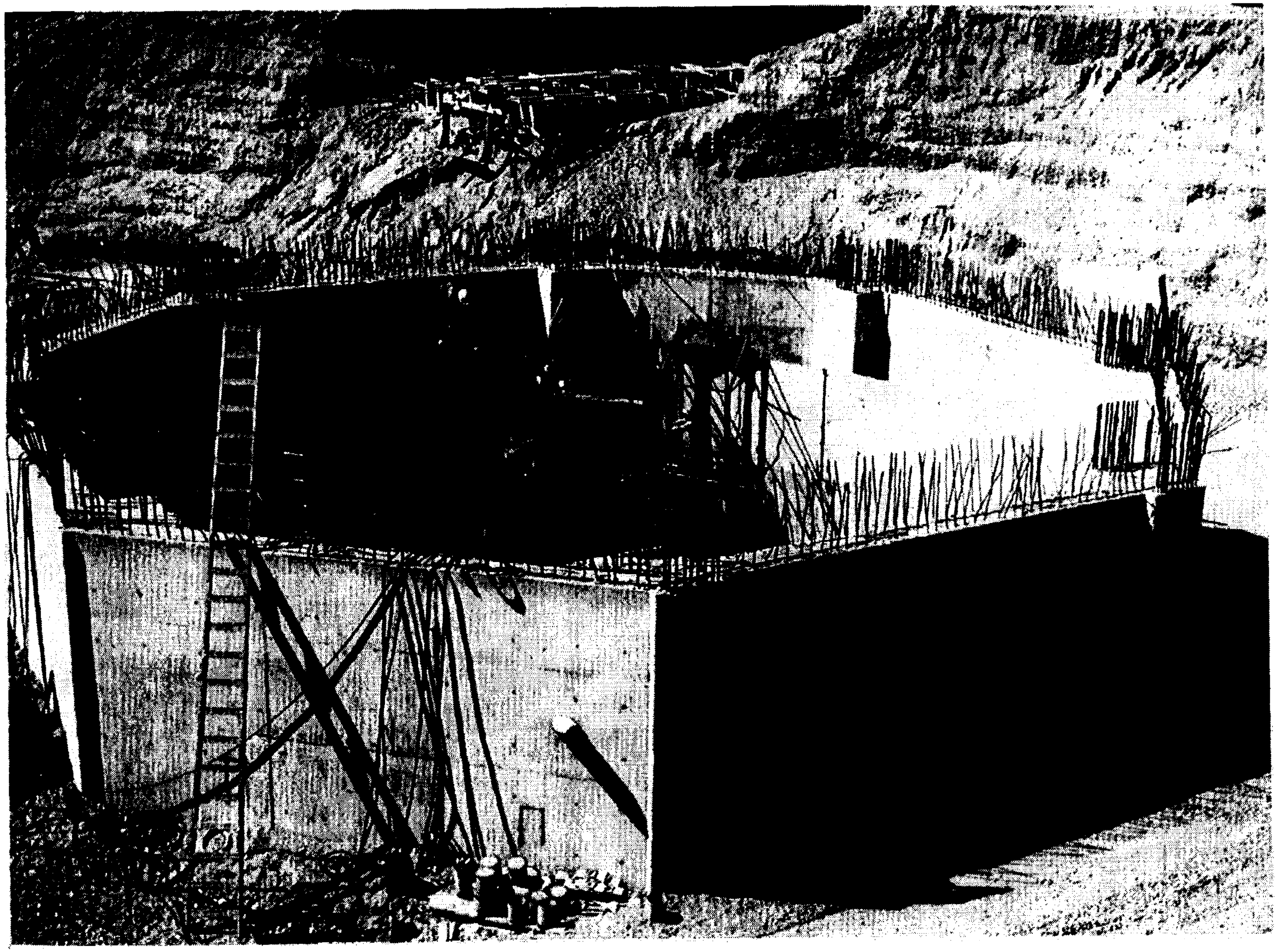

Figure 20. Octagonal, Poured-in-Place Vault for WM-180, Typical of Two Vaults

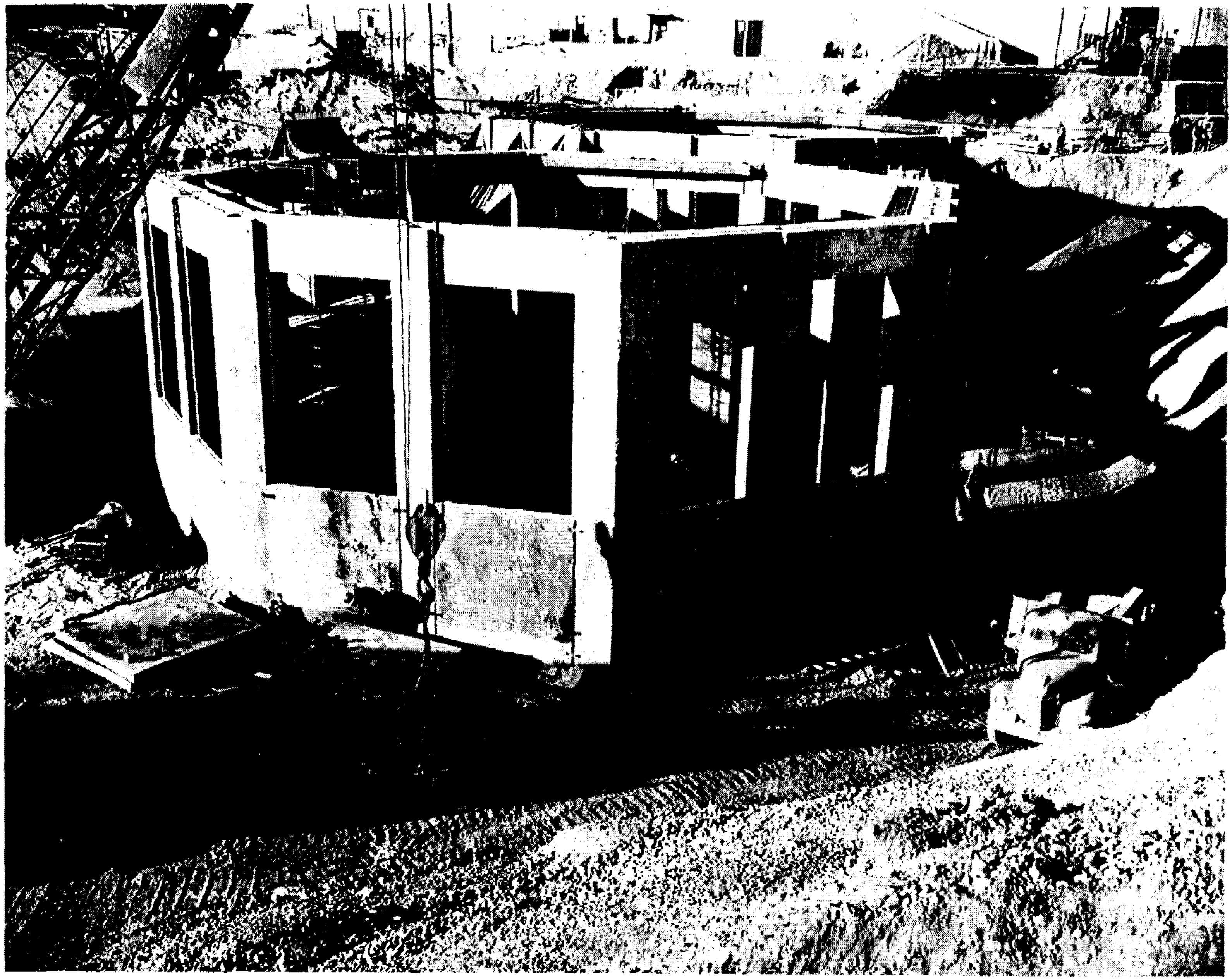

Figure 21. Octagonal, Pillar-and-Panel Vault for WM-182 and -183, Typical of Five Vaults

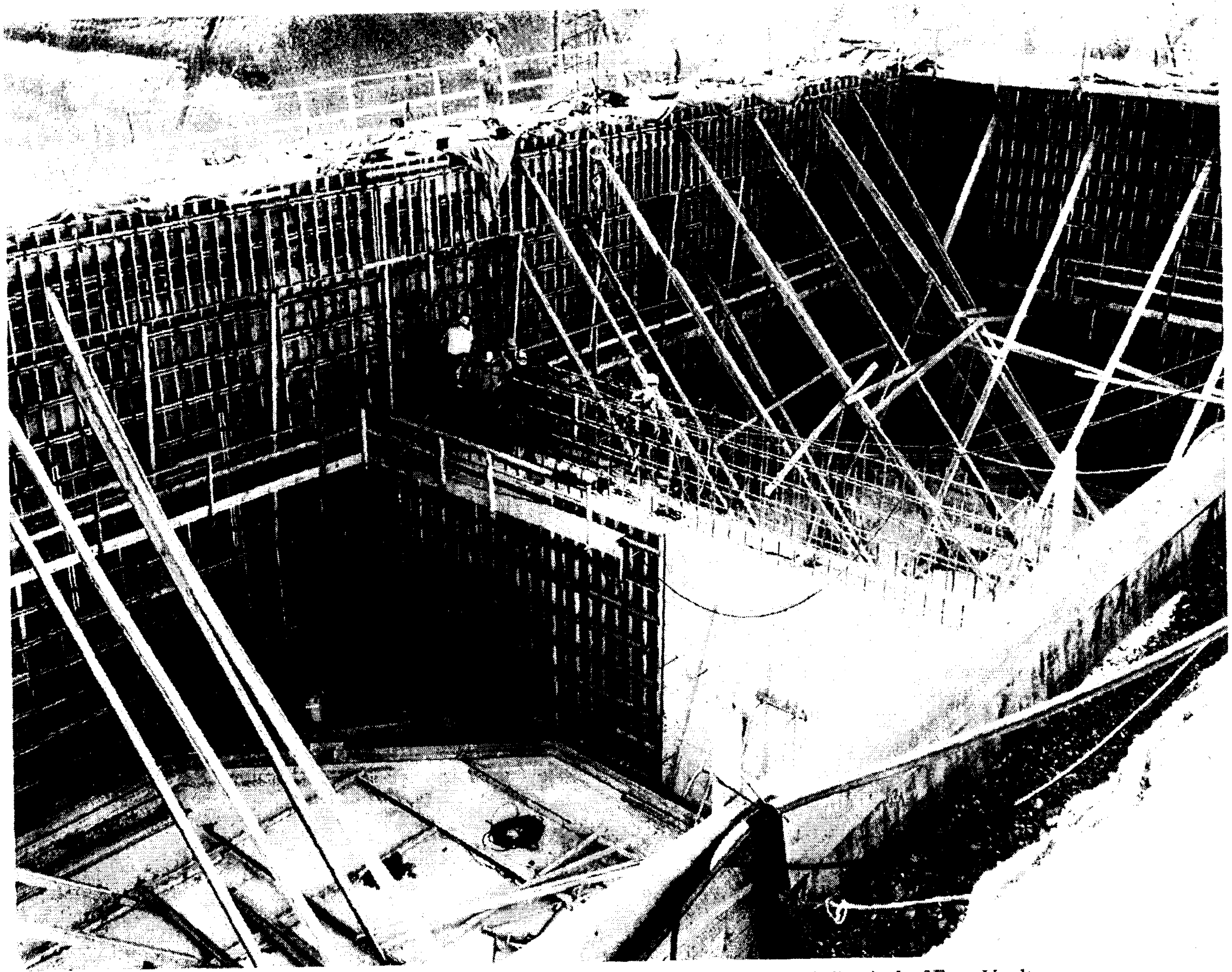

Figure 22. Square, Poured-in Place Vaults for WM-189 and -190, Typical of Four Vaults

Table 2. Summary of Original Waste Tank Design Information.

	WM-180	WM-181	WM-182	WM-183	WM-184	WM-185	WM-186	WM-187	WM-188	WM-189	WM-190
Design Organization	Foster-Wheeler	Foster-Wheeler	Blaw-Knox	Blaw-Knox	Blaw-Knox	Fluor Corp.	Fluor Corp.	Fluor Corp.	Fluor Corp.	Fluor Corp.	Fluor Corp.
Tank Subcontractor	CBI	CBI	CBI	CBI	CBI	CBI	CBI	Hammond Iron	Hammond Iron	Industrial Contractors	Industrial Contractors
Years Constructed	1951-1952	1951-1952	1954-1955	1954-1955	1954-1955	1957	1955-1957	1958-1959	1958-1959	1964	1964
Initial Service Date	1954	1953	1955	1958	1958	1959	1962	1959	1963	1966	Spare
Design Codes	Unknown	Unknown	API-12C	API-12C	API-12C	API-12C	API-12C	API-12C	API-12C	API-650	API-650
Cooling Coils	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Tank Diameter (feet)	50	50	50	50	50	50	50	50	50	50	50
Tank Height To Springline (feet)	23	23	21	21	21	21	21	21	21	21	21
Tank Capacity (gal)	318,000	318,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000
Lower Tank Thickness (inches)	0.3125	0.3125	0.3125	0.3125	0.3125	0.3125	0.3125	0.3125	0.3125	0.3125	0.3125
Upper Tank Thickness (inches)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Corrosion Allowance[6] (mils)[7]	Unknown	Unknown	125	125	125	125	125	125	125	125	125
Type of Stainless Steel	347[8]	347	304L	304L	304L	304L	304L	304L	304L	304L	304L
Design Liquid Specific Gravity[7]	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4

[6] Corrosion allowance is the thickness of metal that can be lost from the tank wall and still meet structural and operating requirements.

[7] This is the original design value. Changes in design standards after the tanks were constructed resulted in the corrosion allowance for the tanks being reduced to 50 mils and the specific gravity being set at 1.3, as a result of the seismic studies described in Section 4.3

[8] Some reports state that WM-180 and WM-181 are constructed of Type 348 stainless steel. Type 348 is a subset of 347 with restricted tantalum and cobalt content. However, for INTEC Tank Farm service and Tank Farm-related laboratory corrosion testing, the two are interchangeable.

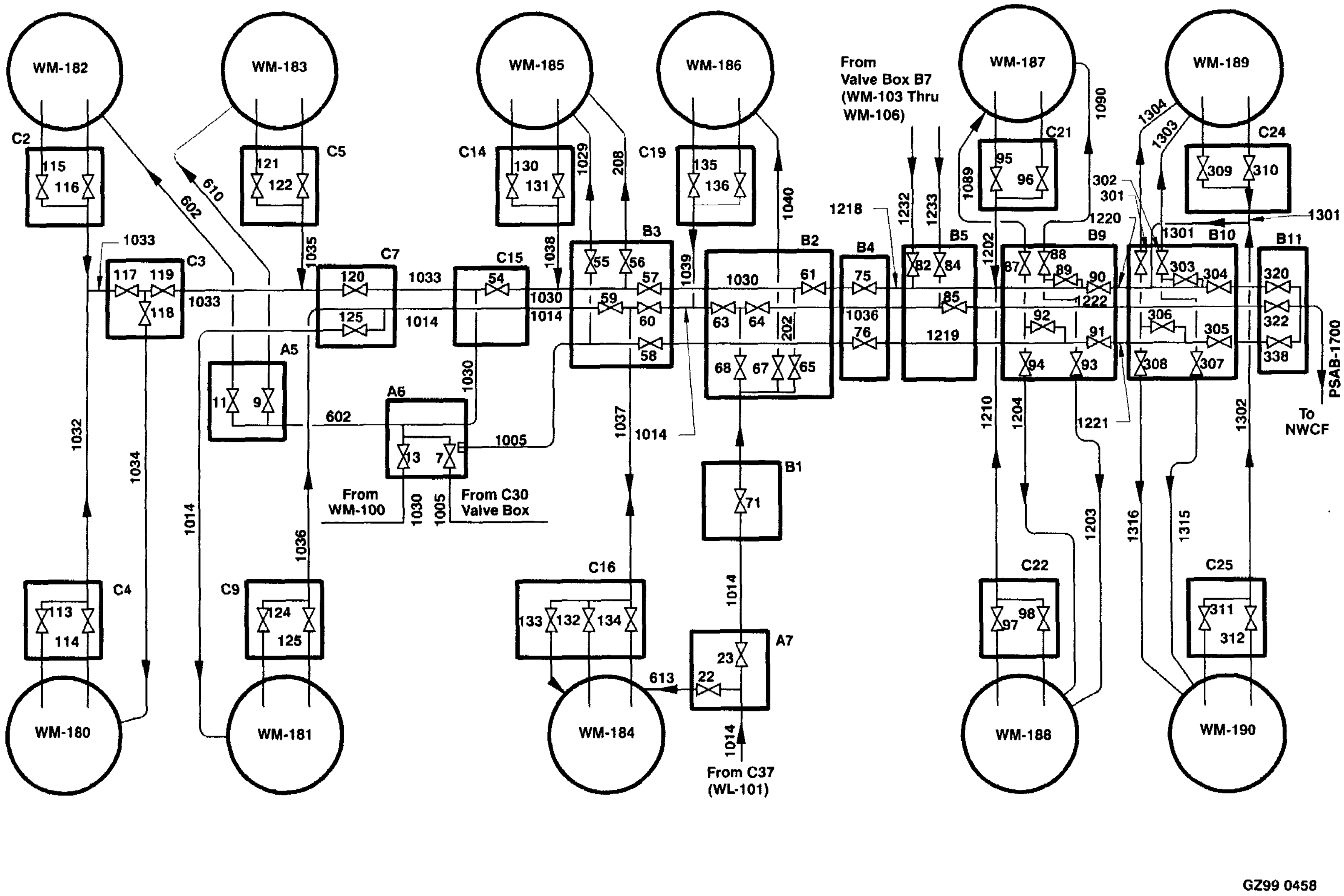

Figure 23. INTEC Waste Tank Farm Schematic

3.2 Tank Details

This section provides, for each tank, a historical summary of its construction and operation, its current status, and plans for its future use. The plans reflect the current baseline, which could be changed by the outcome of the EIS and its ROD. The plans described below do not address closure activities in detail. The first closure plan will be submitted to the State by December 31, 2000, as required by the Second Modification to the NONCO.

WM-180

This is one of the two oldest Tank Farm tanks at the INTEC and was put into service in 1954. It is contained in an octagonal, poured-in-place reinforced concrete vault that meets current seismic requirements[9]. The tank is 50 feet in diameter. It is quite similar to the other Tank Farm tanks except that it is constructed of 347 stainless steel, rather than 304L, and its wall is 23 feet high rather than 21 feet high as in the later tanks. This extra wall height gives this tank a nominal volume of 318,000 gallons rather than 300,000 gallons, but the operating volume is not normally allowed to exceed 285,000 gallons[10]. The tank is equipped with cooling coils. The tank has been filled three times and has contained aluminum fuel reprocessing waste and SBW (Figure B1). The tank currently contains SBW that has been sampled and analyzed sufficiently to determine a calcination flowsheet. The waste has a high sodium concentration and probably will not be further concentrated. The waste contained in WM-180 can be calcined at any time. This tank will be emptied to heel level by December 31, 2012[11].

WM-181

This is one of the two oldest Tank Farm tanks at the INTEC and was put into service in 1953. It is contained in an octagonal, poured-in-place reinforced concrete vault that meets current seismic requirements. The tank is 50 feet in diameter. It is quite similar to the other Tank Farm tanks except that it is constructed of 347 stainless steel, rather than 304L, and its wall is 23 feet high rather than 21 feet high. This extra wall height gives this tank a nominal volume of 318,000 gallons rather than 300,000 gallons, but the operating volume is not normally allowed to exceed 285,000 gallons. The tank does not contain cooling coils. The tank has been filled four times and has contained only SBW (Figure B2). The tank currently contains SBW that has been sampled and analyzed sufficiently to determine a calcination flowsheet. This waste will be blended with WM-184 and/or WM-186 waste, depending on future sample analyses, and concentrated in the High Level Liquid Waste Evaporator (HLLWE) prior to calcination. This tank will be emptied to heel level by December 31, 2012.

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[9] The seismic criteria against which the vaults were evaluated (DBE=PC 4) is more stringent than today's standards (DBE=PC 3). See Section 4.3, Seismic Evaluations, for more detail on this subject.

[10] The volume of liquid stored in a tank is limited to 285,000 gallons so that the contents of a leaking tank plus 5% transfer jet dilution can all fit into the 300,000-gallon spare tank.

[11] December 31, 2012 is the cease use date for the non-pillar and panel vaulted tanks as mandated by the Second Modification to the Notice of Noncompliance Consent Order.

WM-182

This tank was put into service in 1955. It is contained in an octagonal, pillar-and-panel concrete vault that is not as structurally robust as a monolithic design[12]. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume is not allowed to exceed 285,000 gallons. The tank is equipped with cooling coils. The tank has been filled four times and has contained both aluminum and zirconium fuel reprocessing wastes (Figure B3). The tank was emptied to heel level prior to the coupon retrieval and tank inspection in 1999. This tank, as well as the other four tanks having pillar-and-panel vaults, must be emptied to heel level prior to June 30, 2003.[13] This tank will be closed in conformance with RCRA; it will be the first tank to be closed in the Tank Farm. WM-182 and WM-183 will be closed together due to their interconnected piping that makes independent closure impractical, but also simplifies isolation of the tanks. Since these two tanks will be the first to be closed and there is limited experience in this type of closure activity, their closure is expected to be more difficult than subsequent ones. Successful closure of these two tanks should demonstrate to the regulators that the closure method is sound.

WM-183

This tank was put into service in 1958. It is contained in an octagonal, pillar-and-panel concrete vault that is not as structurally robust as a monolithic design. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume is not allowed to exceed 285,000 gallons. The tank is equipped with cooling coils. The tank has been filled three times and has contained aluminum fuel reprocessing wastes, high fluoride decontamination solutions, SBW, and bottoms from the old HLLWE (WC-114) in the Waste Calcining Facility (WCF) (Figure B4). WM-183 has stored a great variety of wastes and, as a result, may contain more accumulated solids on its bottom than other tanks. This tank will continue to receive SBW. Prior to June 30, 2003, its contents will be evaporated and/or transferred to a non-pillar and panel tank. RCRA closure will occur along with WM-182.

WM-184

This tank was put into service in 1958. It is contained in an octagonal, pillar-and-panel concrete vault that is not as structurally robust as a monolithic design. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume is not allowed to exceed 285,000 gallons. The tank does not contain cooling coils. The tank has been filled once and has contained only SBW (Figure B5). Approximately 20,000 gallons freeboard has been retained in this tank for future transfers. The waste in this tank will probably be evaporated along with the contents of WM-181 and the concentrated solution sent to WM-188 and WM-189 prior to June 30, 2003.

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[12] The strength of the various vault designs is discussed in more detail in Section 4.3, Seismic Evaluations.

[13] June 30, 2003 is the cease use date for the pillar and panel vaulted tanks as mandated by the Second Modification to the Notice of Noncompliance Consent Order.

WM-185

This tank was put into service in 1959. It is contained in an octagonal, pillar-and-panel concrete vault that is not as structurally robust as a monolithic design. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume is not allowed to exceed 285,000 gallons. The tank is equipped with cooling coils. The tank has been filled six times and has contained aluminum and zirconium fuel reprocessing wastes as well as high fluoride decontamination waste and SBW (Figure B6). When empty, this tank may be used as the designated spare tank, as discussed in the Second Modification to the NONCO, if WM-190 is put into service.

WM-186

This tank was put into service in 1962. It is contained in an octagonal, pillar-and-panel concrete vault that is not as structurally robust as a monolithic design. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume is not allowed to exceed 285,000 gallons. The tank does not contain cooling coils. The tank has been filled two times and has contained aluminum reprocessing waste and SBW (Figure B7). The SBW in WM-186 is dilute and will require evaporation prior to calcination. This tank will be emptied to heel level prior to June 30, 2003.

WM-187

This tank was put into service in 1959. It is contained in a square reinforced concrete vault. Scoping studies have concluded the vault could be shown to meet the most severe INEEL seismic criteria, more stringent than the current seismic requirements for the vault. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume is not allowed to exceed 285,000 gallons. The tank is equipped with cooling coils. The tank has been filled five times and has contained aluminum, zirconium, and Fluorinel fuel reprocessing wastes as well as high fluoride decontamination waste and SBW (Figure B8)[14]. The SBW remaining in WM-187 is dilute and will be concentrated prior to calcination. Once it is emptied, it will be used to collect HLLWE concentrates. This tank will be emptied to heel level by December 31, 2012. WM-187 will be RCRA closed together with WM-188, -189, and -190 after 2012.

WM-188

This tank was put into service in 1963. It is contained in a square reinforced concrete vault. Scoping studies have concluded the vault could be shown to meet the most severe INEEL seismic criteria, more stringent than the current seismic requirements for the vault. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume is not allowed to exceed 285,000 gallons. The tank is equipped with cooling coils. This tank has been filled five times and has contained zirconium and Fluorinel fuel reprocessing wastes as well as high fluoride decontamination waste and SBW (Figure B9). The waste in WM-188 was the last of the

[14] Fluorinel is a type of zirconium waste and is not shown separately from zirconium waste on the figures in Appendix B.

HLW in the Tank Farm. This tank was emptied to heel level by calcination in February 1998. Tank WM-188 will be used to collect the concentrated waste from HLLWE operations. This tank will be emptied to heel level by December 31, 2012 and will be RCRA closed along with the other square-vaulted tanks after 2012.

WM-189

This tank was put into service in 1966. It is contained in a square reinforced concrete vault. Scoping studies have concluded the vault could be shown to meet the most severe INEEL seismic criteria, more stringent than the current seismic requirements for the vault. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume is not allowed to exceed 285,000 gallons. The tank is equipped with cooling coils. This tank has been filled five times and has contained zirconium and Fluorinel fuel reprocessing wastes as well as high fluoride decontamination waste, bottoms from the old HLLWE (WC-114) in the WCF, and SBW (Figure B10). The waste currently in WM-189 is the HLLWE concentrate from the WM-185/-187 blend and is planned to be calcined during the current Calciner run. Once WM-189 is emptied, it will be used to collect HLLWE concentrate. This tank will be emptied to heel level by December 31, 2012, and will be RCRA closed along with the other square-vaulted tanks after 2012.

WM-190

This tank was never put into service for HLW storage as designed, but was retained as the designated spare tank for use in emergencies. Over many years, approximately 7000 gallons of accumulated vault sump water and HLLW, which leaked through closed valves, collected in the tank. This waste was pumped from the tank in 1982 (Figure B11). System modifications and repairs were made to correct the problems and no subsequent pumping of the tank has been required. The tank is currently estimated[15] to contain only 500 gallons of solution. The tank is contained in a square reinforced concrete vault. Scoping studies have concluded the vault could be shown to meet the most severe INEEL seismic criteria, more stringent than the current seismic requirements for the vault. The tank is 50 feet in diameter, is constructed of 304L stainless steel, and has a side wall that is 21 feet high. The tank has a nominal volume of 300,000 gallons, but the operating volume would not be allowed to exceed 285,000 gallons except when used as the spare tank in an emergency situation. The tank is equipped with cooling coils. This tank will be kept empty as long as possible to retain maximum use flexibility in future Tank Farm operations. If used, this tank will be emptied to heel level by December 31, 2012. It will be RCRA closed along with the other square-vaulted tanks after 2012.

3.3 Ancillary Equipment

The ancillary equipment associated with the Tank Farm consists of the waste transfer systems, (transfer piping, transfer jets and air lifts, sump jets, etc.) and the parts of the off-gas systems that are exposed to mixed liquid waste.

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[15] None of the liquid level detection instruments function at this low liquid level.

Waste Transfer Systems

The Tank Farm waste transfer system consists of the transfer piping, transfer valves, transfer jets and airlifts necessary for the transfer of liquid waste into, out of, and between the Tank Farm tanks. The following description includes the secondary containment and valve boxes associated with the transfer system.

The transfer piping is fabricated of 304L or 347 stainless steel welded pipe. The pipelines are sloped to allow draining in the normal direction of liquid flow (e.g. inlet piping sloped into the tank, outlet piping sloped away from the tank). The pipe sizes range from ½ inch to 4 inches (generally schedule 40) depending on the transfer flow rate required for the specific transfer. Most of the transfer pipelines are encased in 4-inch to 6-inch 300 series stainless steel pipe or in 300 series stainless steel lined concrete troughs to provide secondary containment. The encasements are sloped so that any leakage drains into the tank vaults, the valve boxes, or the receiving buildings where leak detection systems are installed.

The valves used to direct the flow of transferred waste into, out of, and between the Tank Farm tanks are fabricated of 304L or 347 stainless steel and are located inside concrete valve boxes lined with 300 series stainless steel which provide the secondary containment. The transfer pipeline valves are operated either remotely or by reach rods from the top of the valve boxes to limit the radiation exposure to the operations personnel. The valves used in the Tank Farm are primarily two types, high performance ball valves and bellow sealed globe valves. Both types are designed for very low packing/steam seal leak rates and are welded into the pipelines. The newer ball valves are also designed to be repaired with remote tools from the valve box lid, while the older globe valves require a physical entry into the valve box for the "hands on" repair.

If a transfer line or valve were to leak, the waste solution would flow into one of the valve box sumps where the leaked waste would be collected and radiation monitors would detect the leak. The older style valve boxes have drain lines that remove any liquid leaked into the valve box sumps by allowing it to drain into one of the tank vault sumps. The valve boxes with these drain lines are required by the NON Consent Order to be removed from service or upgraded since the drain lines allow leaked waste to drain into the unlined tank vault sumps. The upgraded valve boxes have had the drain lines sealed or modified so that any leaked liquid will drain into and be collected in a 300 series stainless steel lined sump. In addition to the leak detection radiation monitor, each modified valve box has a level indicator or alarm for liquid level detection and a steam transfer jet to remove any collected liquid.

Two major Tank Farm transfer line leaks have occurred during the Tank Farm history. Inadequate design for today's regulations, poor construction practices, and inadequate operational procedures for leak detection caused them.

The leak from transfer line 3-inch PUA-1005[16] that created Environmental Controlled Area (ECA) 28 was caused by a 1/8-inch hole being drilled in the transfer line while the carbon steel

[16] The abbreviations PUA, PWA, WRN, and WRV, which are used in piping descriptions in this section, are AE piping specification and valve identifiers.

encasement cover was being installed in 1955-56. The volume leaked during each transfer was so small that instrumentation installed at the time was not able to detect the liquid loss and the carbon steel encasement cover collapse, due to corrosion, did not allow the liquid to drain into the leak detection sumps. The leak (estimated at a total of 120 gallons of HLW) was discovered in October 1974. All of the type of encasement that caused this leak has been replaced.

The leak from transfer line 3-inch WRN-1037 which created ECA 31 was caused by the connection of a stainless steel primary transfer line, 3-inch PWA-1014, to a carbon steel transfer line, 3-inch WRN-1037, designed to be used if the cooling water became contaminated. Valve WRV-147 was the block valve installed to prevent acidic waste from coming into contact with the carbon steel transfer line. This valve either leaked or was left partially open during a 271,000-gallon waste transfer in November 1972 and the leak location was such that the leaking liquid would not flow into the leak detection sumps. The volume leaked (over 14,000 gallons) during the transfer was large enough that instrumentation detected the liquid loss; however, the operating procedures did not require volume balances during transfers. The leak was discovered in September 1975. All of the carbon steel transfer piping connected to stainless steel transfer piping has been disconnected and removed from service. The operating procedures now require a volume balance after each transfer and transfer volumes are normally limited to a maximum of 20,000 gallons.

Off-Gas Systems[17]

The Tank Farm off-gas system consists of the Vessel Off-Gas system (VOG) and the Pressure/Vacuum Relief system (PVR) necessary for the transfer of waste into, out of, and between the Tank Farm tanks.

The Tank Farm VOG system provides a slight vacuum in the Tank Farm tanks so that any gases generated, air used by the monitoring instruments, and air exchanged during transfers are vented from the tanks and not allowed to build up and pressurize the tank. The VOG consists of 4-inch to 12-inch (generally schedule 10 or 40) 304L or 347 stainless steel welded pipe connecting the top of each tank to the VOG filtering system located in CPP-604. The VOG lines run throughout the Tank Farm and are buried 6-12 feet below grade.

Eight of the tanks are connected to four off-gas condensers, which were designed to remove moisture from the offgas under high temperature conditions for the liquid waste. Since the waste is maintained at fairly low temperatures (less than 35°C), the condensers are not needed or used to cool the offgas. Three of the condensers have been disconnected from the water supply. The condensers still act as drain points to drain any moisture condensed from the offgas back into the Tank Farm tanks. The amount of liquid condensed in the off-gas lines is minimal (probably none, but any liquid condensed would be a mixed waste. The condenser drain lines do not have adequate secondary containment for transferring mixed waste.

[17] Not all of the off-gas system is considered to be RCRA ancillary equipment. However, since the drain lines carry mixed liquid waste, all of the off-gas system is described in the ancillary equipment section for completeness.

The PVR system in the Tank Farm provides an alternate route to vent the Tank Farm tanks so that any gases generated, air used by the monitoring instruments, and air exchanged during transfers are not allowed to build up and pressurize the tank. It consists of 10-inch to 12-inch 304L or 347 stainless steel pipe connecting the top of each tank to pressure and vacuum relief valves located in relief valve pits near each tank. The pressure relief side of the valve vents the offgases to the Ventilation Atmospheric Protection filtering system located in CPP-649 if a pressure is generated inside the tank. The vacuum relief side of the valve allows air to be drawn into the tank if a vacuum is generated inside the tank. The PVR valves can pass up to 1,000 cubic feet per minute of air depending on the pressure or vacuum generated. The PVR lines run throughout the Tank Farm and are buried 8-12 feet below grade.

Since the PVR system downstream of the relief valves is a standby back-up system, it normally does not have any air flowing through it. During such static air conditions, small amounts of moisture could condense in the low spots in these sections of line. This liquid would also be considered mixed waste. A recently completed Tank Farm upgrade project replaced most of the PVR piping downstream of the relief valves. This project provided drain lines with secondary containment, both constructed of 304L stainless steel, at the low points to drain any liquid into the PEW Evaporator system. The drain lines installed by this upgrade project have adequate secondary containment for transferring mixed waste.

All metallic components of waste transfer and off-gas systems that contact the soil are protected from external corrosion by the cathodic protection system. The cathodic protection system consists of a system of electrical rectifiers and anodes, which applies sufficient electrical potential to the interconnected underground metallic structures to prevent the oxidation/corrosion reaction from occurring.

4. TANK FARM MONITORING AND EVALUATION

4.1 Liquid Monitoring

There are two Tank Farm liquid monitoring systems: the tank monitoring instrumentation and the transfer line leak detection instrumentation. The tank monitoring instrumentation for each tank consists of three independent tank level instruments, sump level instruments, pressure/ vacuum instrument, specific gravity instrument, and temperature instruments. The transfer line leak detection instrumentation consists of leak detection radiation monitors installed in each valve box and encasement sump and level indicators or alarms installed in valve boxes and encasement sumps that do not have drain lines.

The general operating procedures require that before any waste transfer can be made to, from, or within the waste Tank Farm, instrumentation for the tanks and transfer lines involved must be in service. Transfer forms must be completed, and verification made that the transfer does not interact with other transfers. Transfers are made according to appropriate procedures in which the positioning/repositioning of valves require the presence of at least two qualified waste processing operators or one operator and a qualified member of waste processing supervision, both of whom must agree that the correct valves are being correctly positioned. Verification of the valve transfer list is made using current facility working drawings.

Tank Farm operations are administratively controlled. The volumes of radioactive liquid waste in WM-180 through WM-189 are limited to 285,000 gallons per tank based upon the allowable stress and corrosion limits[18]. WM-190 is currently held in reserve for use in emergency conditions and can be filled to 300,000 gallons. At least one of the liquid level detection instruments for each 300,000-gallon tank must be in service at all times. The sump-vault instrumentation may be used for no longer than 24 hours should in-tank level instruments become inoperable. When the sump-vault instrumentation is used, it must be monitored every two hours to ensure that no tank leakage has occurred. When a 300,000-gallon tank-level recorder range is changed, the level recorder alarm must be recalibrated. Also the indicated volume in the 300,000-gallon tank must be the same before and after the range change; if a discrepancy occurs, shift supervision resolves the discrepancy before transfers to or from the affected tank resume.

Special radiation monitoring equipment provides indication of potential transfer equipment failures. Valve-box, radiation-rate instrumentation must be operable during transfer of radioactive waste in waste transfer lines associated with the valve boxes. Ratemeter readings are taken before, during, and after each transfer.

[18] Prior to 1981, the maximum fill volume was set at 285,000 gallons so that the contents of a full, leaking tank, plus 5% steam jet dilution, could all be transferred into the 300,000-gallon emergency spare tank. As a result of the seismic evaluations, which began in 1981 and were confirmed by a series of evaluations performed from 1988 to 1994, the maximum fill volume was retained at 285,000 gallons, but this volume was a result of calculations involving allowable stresses, tank wall thickness, and tank wall corrosion allowance. These studies are described in Section 4.3, Seismic Evaluations.

The documentation for transfers is performed on liquid transfer sheets and other data sheets. These sheets require completion of volumetric calculations and volume limit checks. The batch transfer sheets reference the appropriate operating procedures. Notification of plant supervision is made when the volume transferred is greater than that received and any discrepancy is resolved.

The leak detection system for the tanks consists of conventional pneumatic differential pressure instrumentation and specially designed and constructed radio frequency probe instrumentation in the tanks, conventional differential pressure instruments in the tank vault sumps, and radiation detectors in diversion and valve box sumps. If a leak were to occur in any tank, the waste solution would flow into the concrete vault sumps, and would be reflected by a decrease in the tank-liquid level, and a corresponding increase in the sump level. The leak detection system for the piping system consists of radiation monitors in diversion valve boxes, and selected pipe encasements. These liquid level monitoring systems allow detection of leaks from the tanks of as little as 50-100 gallons. The valve box radiation monitors, which monitor the most probable leak locations, can detect leaks of less than one gallon.

4.2 Waste Tank Corrosion Monitoring

An active program to monitor the materials performance of the tanks has been in place since Tank Farm operations began. The program originally consisted of (1) laboratory studies to evaluate and confirm the corrosion acceptability of the fabrication materials and methods with stored liquid wastes, (2) routine visual and instrumental inspections, and (3) the use of corrosion coupons exposed to the actual liquid wastes stored in the tanks. The most authoritative data pertaining to the materials performance of the tanks are obtained from the corrosion coupons. Corrosion coupons, fabricated from equivalent grades of stainless steels to model the corrosion performance of the tank materials, have been placed in all waste tanks suspended at various levels to be covered by the liquid contents of the tank after they were in service. The details about which alloys were tested and the designs and pre-treatments of the coupons are presented in References 7, 8, 9, and 10, along with details of how the coupons were suspended inside the tanks.

During the four decades of operation, a wide variety of types of nuclear fuels have been received and processed at the INTEC. Each type of fuel reprocessed has required its own unique chemical dissolution and separations flowsheet and operating conditions for effective chemical separation of the uranium from the waste products. Extensive chemical research preceded the adoption of each major chemical process before it was used in the plant. The chemical reprocessing of each type of fuel required: (1) dissolving the fuel and its components, (2) separating the uranium from other actinides, fission products, and other dissolved fuel materials, (3) calcining the waste products, and (4) using only chemicals that were acceptably non-corrosive to the available facilities at every step.

Whenever a new process was developed, laboratory tests were conducted in advance to confirm the corrosion acceptability of the anticipated new waste solutions at the maximum expected storage temperatures. Additional laboratory tests were conducted to obtain the same materials performance information for chemical solutions that were expected to be used later to decontaminate various facilities. During the actual fuel processing campaigns, the chemical compositions of the waste solutions were monitored to maintain process control. When necessary, the compositions were chemically adjusted to assure that they met the appropriate specifications before wastes were transferred to the Tank Farm. Considerable attention also was given to making certain that incompatible chemical wastes were not mixed or combined in the same storage tanks. These same types of tests will be performed in the future when predicted waste chemistries fall outside the concentration ranges already tested and established for the tank materials.

The average corrosion rate for uniform corrosion is determined from the coupons' weight losses. Each corrosion coupon weight loss is converted to a corrosion rate with the following equation from Reference 3:

$$\text{Corrosion Rate} = (K \times W)/(A \times T \times D)$$

Where:

K = a constant
T = exposure time in hours
A = area of coupon
W = mass loss in grams
D = density of coupon

Types of corrosion are characterized by the appearances of the metal surfaces in microscopic examination and from various techniques of metallographic analysis. Uniform corrosion rates are useful to provide estimates of tank wall thinning. Localized corrosion, such as pitting, stress corrosion cracking, crevice corrosion and preferential weld attack, is especially important. Analogous to the weakest link in a chain, any localized corrosion or defect that causes any leak at all compromises the integrity of the entire tank. Therefore, it is essential for corrosion monitoring coupons to be fabricated from materials that are equivalent to those in the tanks and welded to exactly the same standards as applied to the tank.

A program to monitor corrosion in the waste tanks was initiated in 1953 when the first tank was placed in service. This program, using austenitic stainless steel corrosion coupons representative of the materials of construction of the tanks, is continuing. The initial corrosion monitoring plans for the tanks were to retrieve a set of coupons approximately once every five to ten years in order to monitor their progressive corrosion behaviors in the actual waste storage environment. Corrosion coupons have been retrieved from the tanks and analyzed four times in the past: in 1962, 1976, 1983, and 1988. A partial retrieval was also done in 1999. The coupons removed from the tanks are carefully decontaminated in a manner that will not significantly affect the coupon surfaces with respect to their appearances or amounts of surface material that might have corroded away. Blank or control coupons accompany actual tank coupons through the decontamination process, so any corrosive effects from the decontamination can be recognized and given appropriate consideration in the interpretation of the results. After the coupons are weighed, in order to determine general corrosion rates from weight losses, they are also examined microscopically for indications of localized corrosion, such as cracking, pitting, preferential weld attack, or weld heat affected zone attack. The corrosion data are then evaluated and the results reported. These data provide the technical bases from which tank lives can be estimated.

Corrosion test coupons in nine of the eleven waste tanks consist of round pipe sections as shown in Figure 24[19]. These coupons are held on test jigs, shown in Figure 25, which are fabricated of austenitic stainless steel and suspended in the waste tanks by clamping onto stainless steel cables at the 18-inch, 36-inch, and 72-inch levels above the tank bottoms. Test coupons in the WM-180 tank are suspended on jigs that are built of rod or pipe rather than strap material. Corrosion specimens in this tank are oval coupons that appear to be about two-inch diameter sections that have been partially flattened to form stressed areas. The test coupons exposed in Tank WM-181 are held on smaller stainless steel clamps that are flat. These coupon holders are clamped flat against the suspension cable. The test coupons are held on small hooks welded to the support assembly. There are only a few of these test coupons remaining in the tank. The length of immersion exposure reported for individual coupons from each tank varies due to the changing levels of waste solutions held in each tank during the exposure period.

During the corrosion coupon recovery operation in 1987-1988 additional corrosion coupons, shown in Figure 26 were placed in the waste tanks. These coupons were exposed on or near the tank bottom to attempt to measure the corrosion that is occurring in this area. During a recent video inspection, it was discovered that the coupons placed in WM-188 in 1988 had become entangled in the access riser piping and therefore were not placed in the tank liquid as intended.

[19] The corrosion coupons are fabricated of the same materials as the waste tank in which they are exposed. Type 316 coupons are shown on Figure 24 since these were used in Tanks WM-103, -104, -105, and -106, which were constructed of Type 316 stainless steel. Since use of these small (30,000-gallon) Tank Farm tanks was discontinued many years ago, they are not discussed in this report.

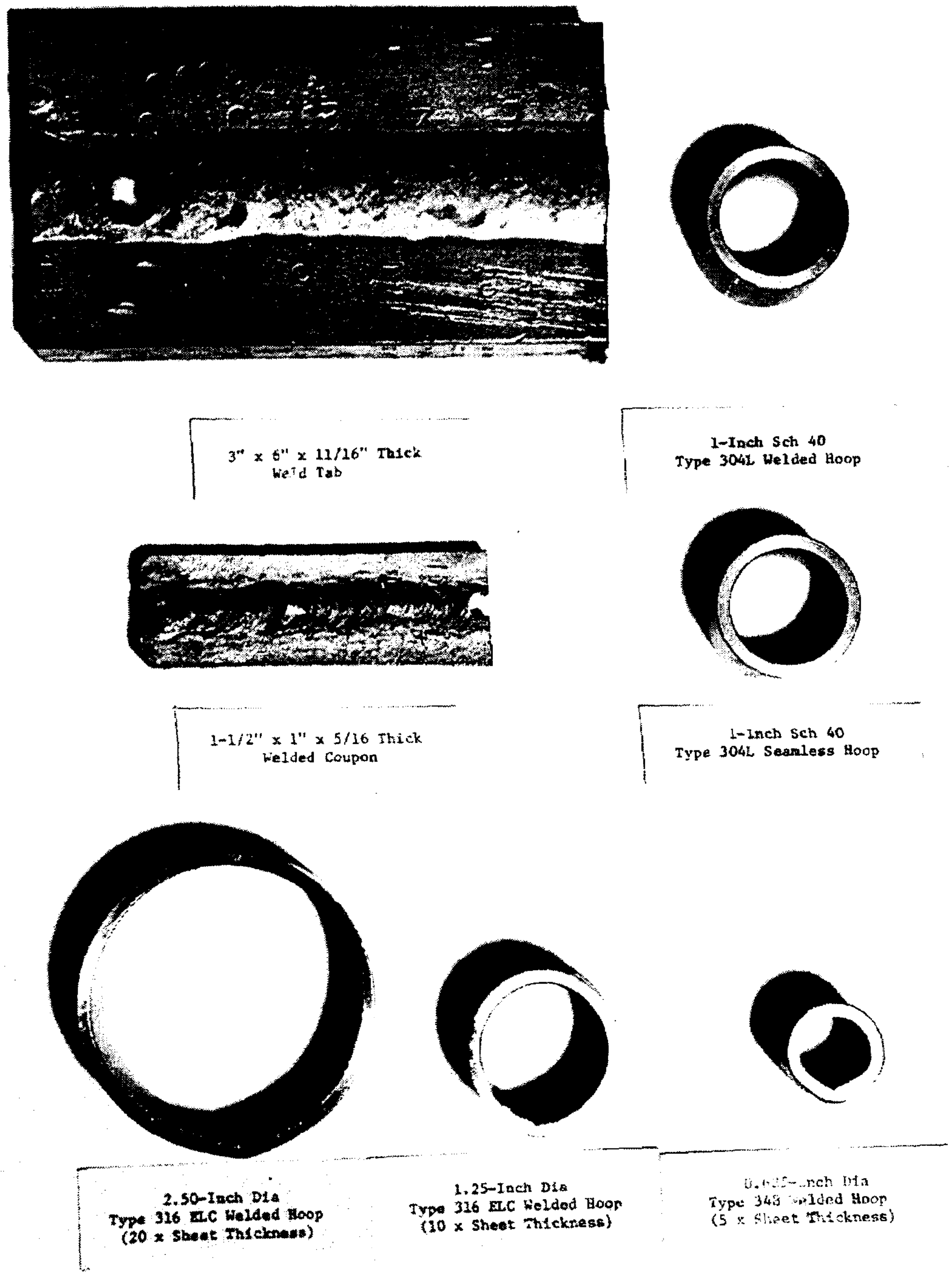


Figure 24. Types of Corrosion Coupons Exposed in INTEC Waste Tanks

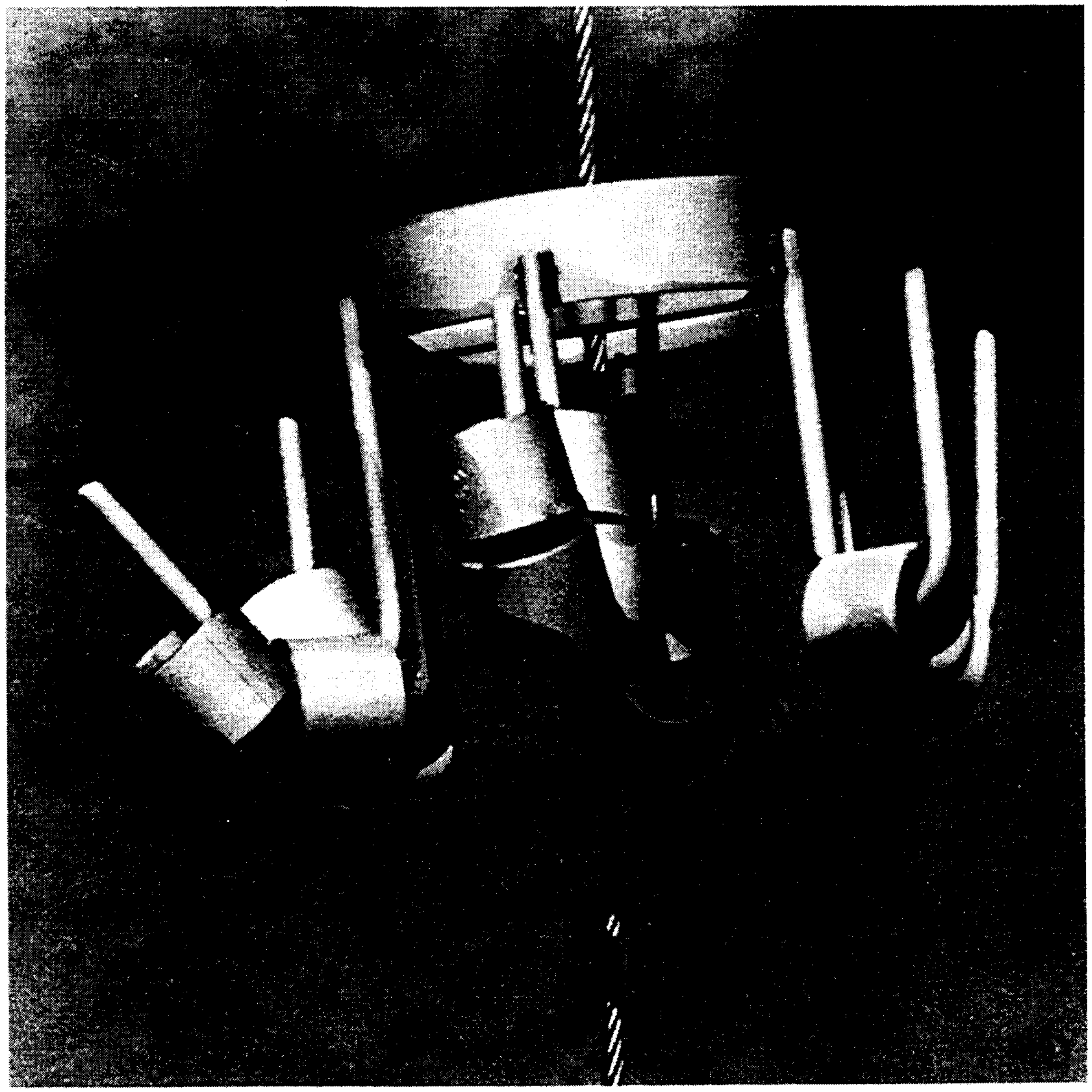


Figure 25. Corrosion Specimen Test Jig

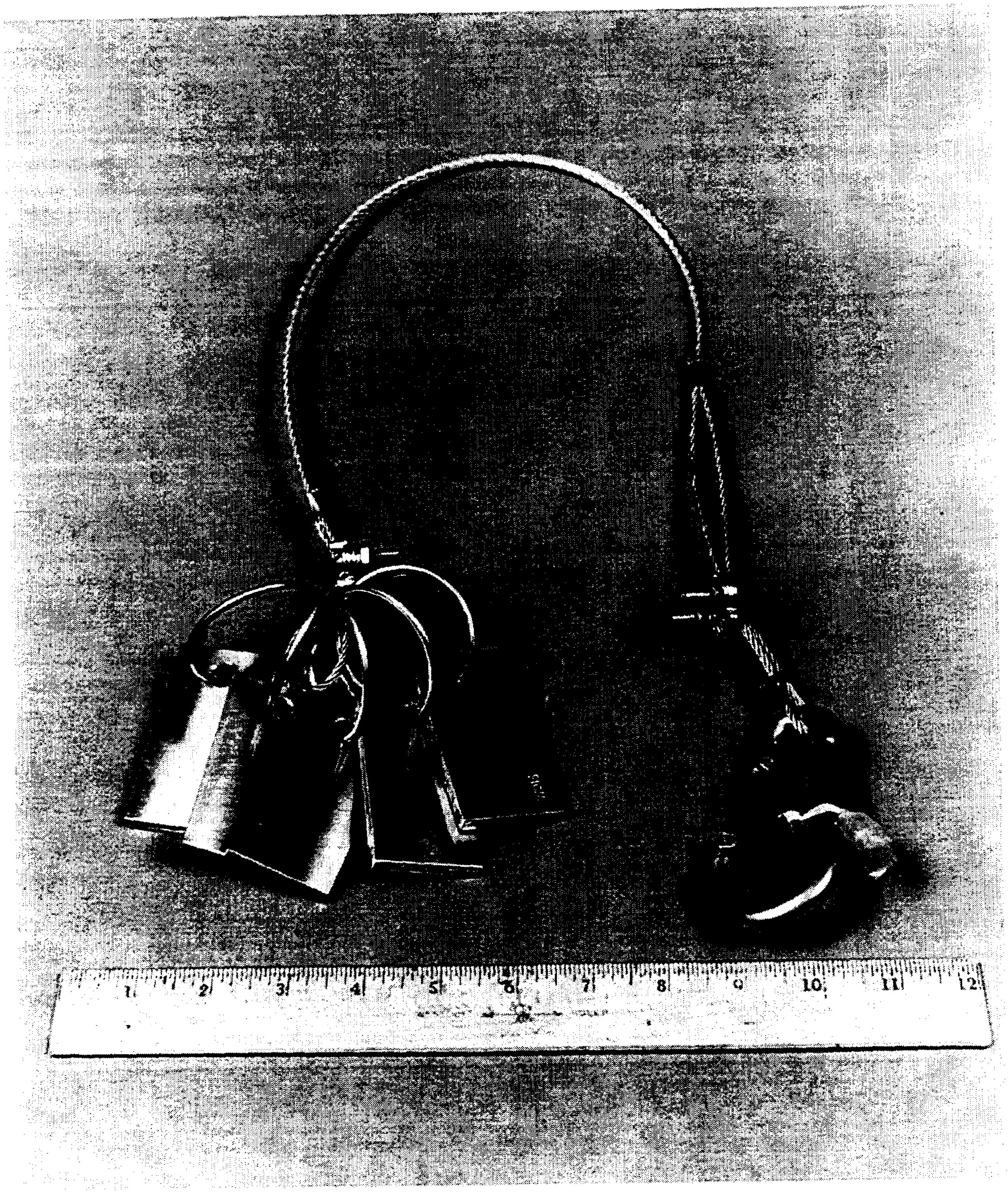


Figure 26. Corrosion Coupon Assembly for Tank Bottom Evaluation

The results from the latest (1988) full corrosion coupon evaluation (Reference 7) indicate that the uniform corrosion rates of test coupons recovered from these tanks are not excessive. As shown in Table 3, the highest corrosion rates have been sustained in the tanks used for storage of the zirconium first-cycle wastes. Corrosion coupons from the three tanks being used for this service (WM-187, -188, and -189) show average uniform corrosion rates of 7.9×10^{-3} to 5.3×10^{-2} mil[20] per year with an average rate for the three tanks of 2.9×10^{-2} mil per year. The maximum corrosion rate observed in first-cycle zirconium waste was for Tank WM-188 with a rate of 5.3×10^{-2} mil per year indicated by coupons at both the 36- and 72-inch exposure levels. Calculations based on this maximum observed uniform corrosion rate in 1988 indicate a maximum metal loss from the internal tank surfaces of 1.2 mil over the WM-188 service life of 23.3 years. This maximum metal loss of 1.2 mils is small compared to the design corrosion allowance of 125 mils or the revised corrosion allowance of 50 mils that resulted from the seismic studies (see Section 4.3). Figure 27 graphically shows this extremely small amount of corrosion compared to the corrosion allowance and mechanical design allowance of the vessel. It should be noted that if the corrosion allowance were consumed or penetrated, there would still be the 200-mil (0.200-inch) mechanical design allowance left to preclude leakage.

[20] "mil" is a unit of length equal to 0.001 inch.

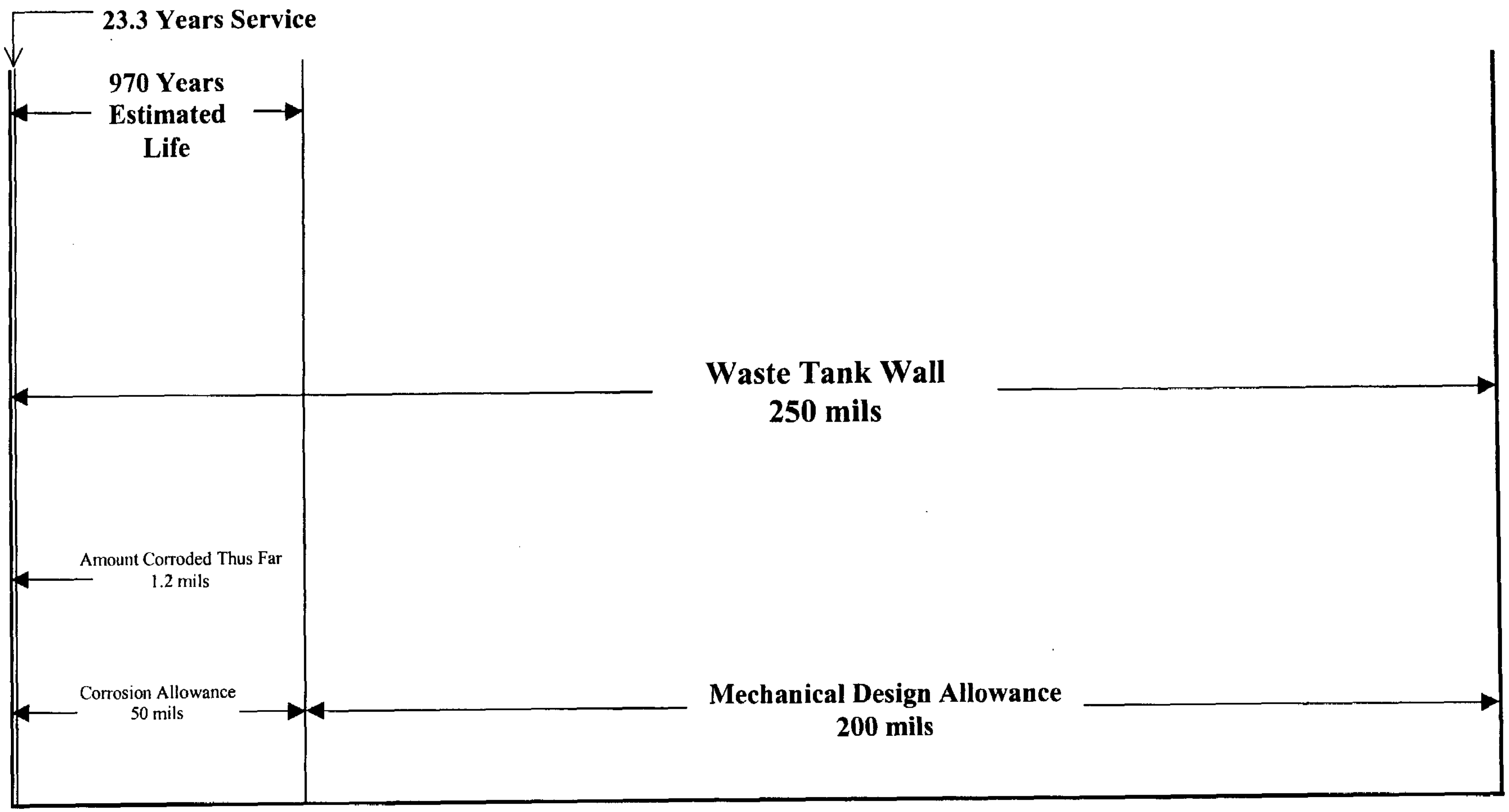


Figure 27. Scaled Drawing of the Maximum Corrosion in the Waste Tanks

The corrosion coupons in the non-zirconium first-cycle waste (WM-182) showed an average uniform corrosion rate of 1.3×10^{-2} mil per year. The maximum corrosion rate observed for any coupon from this tank was 1.4×10^{-2} mil per year. Calculations using this maximum corrosion rate indicate a metal loss from the internal surfaces of the vessel of 0.46 mil over the 32.9 years of tank service.

Corrosion in SBW is significantly less than that observed for first-cycle wastes. The average uniform corrosion rate for test coupons from tanks containing sodium waste (WM-180, -183, -184, and -186) is 6.6×10^{-4} mil per year. The maximum corrosion rate observed in any of these four vessels was 3.4×10^{-3} mil per year for a test coupon at the 18-inch exposure level in Tank WM-186. Calculations using this maximum corrosion rate and the 25.8-year service life of this vessel indicate a metal loss from the tank internal surfaces of 8.8×10^{-2} mil due to uniform corrosion.

It should be noted that the reported corrosion rates are uniform corrosion rates. The fact that these test coupons show only uniform corrosion does not eliminate the possibility of localized corrosion in the tanks. However, physical examination of the corrosion coupons did not reveal any significant localized corrosion. The absence of significant localized corrosion on the coupons does constitute a good indication that the inner tank surfaces are in the same condition.

Table 3. Corrosion Data For Coupons Retrieved From Waste Storage Tanks In 1987-88. (Reference 7)

Tank No.	Initial Tank Service Date	Tank Construction Material (SS)	Tank Service (Years)	Coupon Exposure (Years)[a]	Average Corrosion Rate (mpy)[c,d]	Average Indicated Metal loss from Tank Internal Surfaces (mil)[d]	Maximum Uniform Corrosion rate Observed (mpy)	Metal Loss from Tank Based on Maximum Corrosion Rate (mil)
WM-180	Oct. 1954	347	35.2	9.8[b]	4.3×10^{-4}	1.5×10^{-2}	4.5×10^{-4} (72")	1.6×10^{-2}
WM-181	Aug. 1953	347	35.2	32.8	2.2×10^{-4}[e]	7.7×10^{-3}[f]	2.3×10^{-4}[e]	8.1×10^{-3}[f]
WM-182	Feb. 1956	304L	32.9	25.4	1.3×10^{-2}	4.3×10^{-1}	1.4×10^{-2} (36")	4.6×10^{-1}
WM-183	Jul. 1958	304L	29.8	28.0	1.3×10^{-3}	3.9×10^{-2}	1.6×10^{-3} (36")	4.8×10^{-2}
WM-184	Sep. 1958	304L	29.9	29.0	1.3×10^{-5}	3.9×10^{-4}	2.0×10^{-5} (72")	6.0×10^{-4}
WM-185	Feb. 1959	304L	29.0	25.5	4.1×10^{-2}[e]	1.2[f]	4.2×10^{-2}[e]	1.2[f]
WM-186	Mar. 1962	304L	25.8	24.2	8.8×10^{-4}	2.3×10^{-2}	3.4×10^{-3} (48")	8.8×10^{-2}
WM-187	Dec. 1959	304L	28.2	27.7	2.7×10^{-2}	7.6×10^{-1}	2.9×10^{-2} (72")	8.2×10^{-1}
WM-188	Jun. 1963	304L	23.3	20.0	5.3×10^{-2}	1.2	5.3×10^{-2} (36 & 72")	1.2
WM-189	Feb. 1966	304L	22.0	21.8	7.9×10^{-3}	1.7×10^{-1}	1.4×10^{-2} (72")	3.1×10^{-1}
WM-190	Spare	304L	0	0	0	0	0	0

(a) Coupons at the 18-inch level.
(b) New coupons placed in vessel June 1978.
(c) Coupons recovered in 1987-1988.
(d) "mpy" stands for "mils per year". "mil" is a unit of length equal to 0.001 inch.
(e) Data reported in 1983.
(f) Metal loss calculated using corrosion rate reported in 1983 and total tank service shown.

Additional new coupons were placed on the tank bottoms at the same time as the coupon recovery operation in 1988 to allow future evaluation for any localized corrosion occurring in this area. The bottom coupons were retrieved from Tank WM-182 for examination in late 1999. The evaluation of these coupons showed no evidence of accelerated or localized corrosion from solids on the tank bottom. These results are reported in more detail in Section 4.8.

A review of Table 3 indicates that the tanks having the highest calculated metal loss are WM-182, WM-185, WM-187, WM-188, and WM-189. The higher metal loss shown for the first-cycle zirconium waste tanks (WM-187, WM-188, and WM-189) may be explained by the more aggressive chemistry of the fluoride-containing solution. The higher metal loss in WM-182 and WM-185 also may be attributed to the use of both of these tanks for first-cycle zirconium waste in the past. A prior report (Reference 8) indicates that WM-182 was used in first-cycle zirconium waste service for 9.4 years and WM-185 was used for storing first-cycle zirconium waste for 7.3 years.

Table 4 has been included in this report to present a summary of Tank Farm corrosion information available from all previous reports (References 7, 8, 9, and 10). Table 4 shows the average uniform corrosion rates calculated for the test coupons removed from the waste tanks. (The 1962 data are for maximum corrosion rates.) These data are based on weight losses from the test coupons and the lengths of coupon exposures in the liquids contained in the tanks. The corrosion rates are generally higher for the first period of exposure. This may be attributed to the fact that available 1962 report data reflect only maximum corrosion rates which may have contributed to a positive (conservatively high) bias. In addition, it may be attributed the well-known phenomenon of accelerated corrosion of a freshly exposed new metal surface. The same phenomenon occurs with cyclic corrosion tests of metal alloys in a laboratory setting in which the corrosion rates during the first cycle of exposure are expected to be higher than the rates of subsequent cycles.

Information is also presented in Table 4 concerning the calculated metal loss from each tank based on the observed corrosion rate and the length of time the tank has been in use. Tanks WM-182, WM-187, and WM-189 show higher metal losses for the first period of exposure than for subsequent exposure periods. As with the uniform corrosion rates, it should be noted that each of the metal loss figures from 1976, 1983, and 1988 data are the result of calculations based on the average corrosion rate calculated for coupons removed from the tank and the length of tank exposure. The 1962 data are conservative because they are based on maximum corrosion rates in addition to being from the first exposure cycle.

The following summarizes the results of the corrosion studies from 1953 until the most recent data were obtained from coupons retrieved September 1, 1999:

1. Evaluation of corrosion coupon data indicates that INTEC tanks containing high level waste solutions experienced very little uniform corrosion during their first three decades of service. The greatest average metal loss, calculated from corrosion coupon data (through 1988), was 1.2 mil (0.0012 inch) of metal loss over 23.3 years of exposure in Tank WM-188. Metal losses of this small magnitude (less than 0.5% of the tank wall thickness and 2.4% of the corrosion allowance) are very acceptable for continued long-term utilization of these tanks.

2. The first-cycle zirconium waste solutions were the most corrosive liquids stored in the INTEC Tank Farm.

3. The average metal losses calculated for the first-cycle zirconium waste Tanks WM-187 and WM-188 are the highest observed (0.76 and 1.2 mil). The calculated metal loss for zirconium first-cycle waste Tank WM-189 was much lower (0.17 mil). This variation is probably the result of variations in the compositions of the liquid wastes stored in the tanks.

4. Tank WM-182 (0.43 mil metal loss) currently contains SBW; however, this tank has previously contained zirconium waste for at least 9.4 years.

5. Projected metal losses from the internal walls of tanks containing predominantly sodium wastes are all low (less than 0.039 mil) with the exception of Tank WM-185 (1.2 mil). Previous reports show that Tank WM-185 had contained first-cycle zirconium wastes for at least 7.3 years.

6. These low uniform corrosion rates and the lack of any indication of significant localized corrosion indicate that the passivation layer has effectively formed on the tanks internal surfaces and has not been degraded under the waste storage conditions.

TABLE 4. Summary Of Average Waste Tank Corrosion Data From 1962 To 1988. (Reference 7)

Tank No.	1962 Report (Coupons 1962 or Earlier)		1976 Report (Coupons Recovered 1973)		1983 Report (Coupons Recovered 1981)		1988 Report (Coupons Recovered 1987-88)	
	Coupon Corrosion Rate (Max.)[a] Mpy	Tank Metal Loss mil	Coupon Corrosion Rate (Avg.) 18-inch level mpy[b]	Tank Metal Loss mil[b]	Coupon Corrosion Rate (Avg.)[c,d] mpy	Tank Metal Loss mil	Coupon Corrosion Rate (Avg.) mpy	Tank Metal Loss mil
WM-180	7.9×10^{-3}	4.7×10^{-2}	1.0×10^{-3}	2.0×10^{-2}	9.8×10^{-5}	2.8×10^{-3}	4.3×10^{-4}	1.5×10^{-2}
WM-181	No data avail.	No data avail.	9.0×10^{-4}	1.8×10^{-2}	2.2×10^{-4}[e]	6.3×10^{-3}	2.2×10^{-4}[j]	7.7×10^{-3}[f]
WM-182	1.2×10^{-1}	8.1×10^{-1}	7.0×10^{-3}	1.3×10^{-1}	9.5×10^{-3}	2.5×10^{-1}	1.3×10^{-2}	4.3×10^{-1}
WM-183	1.0×10^{-3}	4.5×10^{-2}	2.0×10^{-3}	3.0×10^{-2}	1.0×10^{-3}	2.3×10^{-2}	1.3×10^{-3}	3.9×10^{-2}
WM-184	7.2×10^{-3}	2.7×10^{-2}	1.0×10^{-4}	1.5×10^{-3}	2.0×10^{-5}[e]	4.7×10^{-4}	1.3×10^{-5}	3.9×10^{-4}
WM-185	2.4×10^{-2}	7.2×10^{-2}	2.0×10^{-2}	2.9×10^{-1}	4.1×10^{-2}[g]	9.3×10^{-1}	4.1×10^{-2}[j]	1.2 [f]
WM-186	Vessel placed in service in 1962		9.0×10^{-4}	9.2×10^{-3}	3.6×10^{-4}	7.0×10^{-3}	8.8×10^{-4}	2.3×10^{-2}
WM-187	9.6×10^{-2}	2.9×10^{-1}	2.0×10^{-2}	2.7×10^{-1}	2.9×10^{-2}[e]	6.3×10^{-1}	2.7×10^{-2}	7.6×10^{-1}
WM-188	Vessel placed in service in 1963		9.0×10^{-2}	7.9×10^{-1}	5.9×10^{-2}[e]	1.0	5.3×10^{-2}	1.2
WM-189	Vessel placed in service in 1966		9.0×10^{-2}[h]	6.4×10^{-1}	9.1×10^{-3}[i]	1.4×10^{-1}	7.9×10^{-3}	1.7×10^{-1}

(a) No average data available
(b) "mpy" stands for "mils per year". "mil" is a unit of measurement equal to 0.001 inch.
(c) New coupons placed in service June 1978
(d) 18-inch level unless otherwise noted
(e) 36-inch level
(f) Based on 1983 corrosion rate and 1988 service time
(g) 72-inch level
(h) Corrosion estimate based on WM-188 data
(i) Data from welded coupons
(j) Data from 1983 report

4.3 Ancillary Equipment Corrosion Monitoring

A specific corrosion monitoring program which addresses ancillary equipment does not exist for the INTEC waste tank system. The reason is that metal losses due to corrosion in the ancillary equipment are substantially lower than in the waste tanks and corrosion monitoring of the waste tanks will conservatively bound the corrosion occurring in the ancillary equipment. The reason for the lower metal losses in the ancillary equipment is that the equipment is in contact with the waste only a fraction of the time that waste is in the tanks. Specifically, once waste enters a tank it is in contact with the tank (at least the tank bottom) 100% of the time until the tank is closed. In the case of the individual INTEC waste tanks, this will be from 45 to 60 years. However, the most often used section of waste transfer line in the Tank Farm has been exposed to waste solutions for the equivalent time of only two months or less than 1/100th of the service time of the tanks.

Corrosion concerns could arise if the ancillary equipment were constructed of materials different from the tanks, had substantially thinner walls than the tanks, or was subjected to higher temperatures than the tanks. Investigation showed that none of these is a significant concern. The ancillary equipment is made of the same materials as the tanks (304L or 347 SS). The bulk of the ancillary equipment consists of transfer lines constructed of pipe, most of which is 3-inch schedule 40 pipe. The wall thickness of this pipe is 0.216 inch; this is very much like the 0.25-inch thick upper walls on the waste tanks.

Since steam jets are used to transfer waste to and from the tanks, the solutions transferred through the ancillary piping could be briefly elevated in temperature. Based on available data, a jet dilution of approximately 4 to 5% appears to be average for a Tank Farm waste transfer. Such a dilution will result in a temperature increase of approximately 24 to 31°C in the waste solution and process piping above the temperature of the waste in the tank. Since present Tank Farm waste solutions are low in radioactivity, they are not cooled. These wastes have come to equilibrium with ambient conditions and range in temperature from 10 to 20°C. Historically some wastes have had slightly higher temperatures, but since the existing wastes are much less radioactive than previous wastes, waste heating due to decay will not occur in the future. This modest temperature gain for a short period will not cause a significant increase in corrosion.

Although a corrosion monitoring program does not exist specifically for the ancillary equipment, anecdotal information does exist. During the many upgrades of the waste transfer piping associated with the Tank Farm, no corrosion failures of the piping or other equipment have been detected. In 1974 a leak was discovered in a transfer line that was due to a hole being inadvertently drilled in the pipe during original construction in 1955-56. To determine the cause of failure, an 8-inch section of pipe containing the hole and a 12-inch section of pipe at a weld joint were cut out for further metallurgical inspection. This inspection indicated the pipe, in general, had suffered very little corrosion damage during its 18 years of intermittent service, and failure was strictly a result of mechanical damage.

Another good example is the WCF quench system. The WCF was designed and built at the same time (late 1950's), by the same architect engineer and construction crews, using the same methods and technology as several of the Tank Farm vessels. The quench system at WCF was made of the same material as the Tank Farm transfer piping. The quench system solution was similar in composition to Tank Farm solution. However it was often significantly higher than Tank Farm solution in chloride and undissolved solids (UDS) concentration. The chloride made the solution more corrosive than Tank Farm solutions and the UDS increased the erosion potential of the solution. The WCF processed four million gallons of waste. At a rate of eighty gallons per hour, this represents fifty thousand hours (nearly six years) of continuous operation. This does not include start-up time, non-radioactive operation, and decontamination operations. The normal operating temperature of the quench tank was approximately 65°C. The quench solution conditions are much more severe from a corrosion standpoint (higher temperature, higher chloride, and longer exposure) than are conditions in the Tank Farm transfer lines. Yet the quench solution piping never failed.

Historically, leaks have occurred from the ancillary equipment, but all of the leaks have been a result of mechanical failures, mostly of valves, and not due to corrosion. There are currently no leaks or expected failures associated with the ancillary equipment.

In summary, the material of construction of the Tank Farm ancillary equipment (transfer piping, valves, jets etc.) is the same as the tanks, but some of the equipment is subject to slightly higher temperatures during solution transfers due to the steam jets than the waste tanks experience. However, the amount of time this equipment has actually been subject to such conditions is very small (two months) compared to the tanks which have been continuously exposed to process solutions for approximately forty years. Because of this, the corrosion coupons in the tanks should be conservatively representative of the uniform corrosion in the ancillary equipment as well.

4.4 Seismic Evaluations

During the late 1980s and early 1990s, various seismic studies were performed on the INTEC Tank Farm. The results of these studies are summarized below. During the late 1980s and early 1990s, the Tank Farm was the topic of intense study and evaluation for a number of reasons, seismic qualification being one of them. Some seismic studies were done earlier than that time, but only the most recent studies are summarized in this report. The studies were all done using the same design basis earthquake (DBE) criteria, 0.24g horizontal ground acceleration. This is equivalent to a Performance Category (PC) 4 using DOE's current requirements for determining natural phenomena criteria[21]. Since the time the evaluations were done, procedures and criteria have changed, and today the Tank Farm would be evaluated as a PC 3 facility, which requires less rigorous seismic criteria (0.18g horizontal ground acceleration) compared to PC 4. The studies are listed in chronological order as References 11 through 17. The following is a brief summary of the results and conclusions of each study.

<u>Reference 11</u>
This was a scoping evaluation of the three styles of vaults that exist in the Tank Farm. The study concluded that the two cast-in-place octagonal concrete vaults enclosing Tanks WM-180 and -181 would likely meet the DBE criteria if a definitive analysis were conducted. The square 2x2

[21] The DOE seismic evaluation criteria are defined in DOE Standards STD-1020, STD-1021, and STD-1022.

vault enclosing Tanks WM-187 through -190 could be overstressed, but would be expected to retain its integrity during a DBE. The five pillar and panel vaults enclosing Tanks WM-182 through -186 were judged to have inherent vulnerabilities, were not ruggedly designed, and were the least likely candidates for further analysis to show they could meet the DBE criteria. Because of this negative statement about the pillar and panel tank vaults, they were never included in the subsequent definitive analyses.

Reference 12

This study was a definitive analysis of the cast-in-place octagonal tank vaults, the 2x2 tank vaults, as well as the tanks themselves. The study concluded neither type of vault met the DBE criteria. The octagonal vaults were qualified to 0.13g acceleration and the 2x2 vaults were qualified to 0.19g acceleration. The pillar and panel tank vaults were not evaluated because the previous evaluation (Reference 11) indicated those vaults would likely not meet the DBE criteria. There were two types of tank designs evaluated; one in which the tanks are anchored to the vault floor (WM-180 and -181) and one in which the tanks are not anchored (WM-182 through 190). The study concluded both types of tank designs met the DBE criteria.

Reference 13

This study was a review of References 11 and 12. It was initiated due to some unanswered questions about the previous definitive analysis (Reference 12) and because the conclusions of References 11 and 12 were at odds about the vaults meeting the DBE criteria. This study concluded Reference 12 used extremely conservative approaches and deficient models that led to the calculation of unreliable demands on the tank vaults. This study sided with Reference 11 in concluding the subject tank vaults could be shown to meet DBE criteria.

Reference 14

This study was a definitive analysis of the two cast-in-place octagonal vaults. The square 2x2 tank vaults were not included in this study. This study concluded the two cast-in-place octagonal vaults met the DBE criteria.

Reference 15

This study was similar to Reference 11 in that it was not a definitive analysis, but rather an overview based on limited approximate calculations and engineering judgment. The evaluation was limited in scope to the pillar and panel tank vaults. The evaluation concluded that the pillar and panel vaults would likely not meet either the DBE seismic criteria or the lesser PC 3 (0.18g acceleration) criteria. Even though the vaults would not be expected to meet the DBE criteria, the study concluded the vaults would not collapse if a DBE were to occur. A DBE would result in some damage to the vault such as flexural cracks in the panels, but the vaults would still be expected to maintain a barrier against the surrounding soil and keep it from intruding into the vault, for example.

Reference 16

Due to questions about the methodology used in Reference 12, this study was initiated to repeat the seismic analysis of the tanks themselves. Again, two types of tanks (anchored and unanchored) were evaluated. This study concluded the unanchored tanks (WM-182 through -190) met the DBE criteria with a 50-mil corrosion allowance except for some nominal exceedences. These exceedences include items such as a 4% value above the acceptance criteria in hoop stresses, for example. However, the report indicated that conservative allowable stress values were used in the analysis, and other codes have higher allowable stresses. It was the opinion of the analyst that such nominal exceedence of the criteria did not materially diminish the ability of the tank to maintain the waste during a DBE. On this basis, the conclusion was the unanchored tanks met the criteria.

The anchored tanks (WM-180 and -181) also met the DBE criteria except at the location of the anchor bolts and the anchor bolt "chair" connections to the vessel. The report acknowledged its analyses were primarily linear elastic and contained conservatisms that could be reduced through more rigorous analyses. The report recommended pursuing a nonlinear analysis of the tank at the anchor bolt chairs. The report's considered opinion was that a more realistic, nonlinear analysis would confirm that the anchor stresses would, at most, result in minor localized yielding in the tank shell, and that the tank shell had considerable excess capacity to accommodate such yielding and maintain its structural integrity.

Reference 17
This analysis was a review of the analysis in Reference 16. It confirmed the unanchored tanks met the DBE seismic criteria. Some of the minor deficiencies, noted in Reference 16, were shown to be adequate using alternate calculations. This study also noted that some of the assumptions and methods used in Reference 16 were conservative.

With regard to the WM-180 and -181 anchor chair overstresses, this study did some scoping calculations, and based on these, recommended further work which would be expected to result in values showing only slight overstresses (approximately 10%) in the anchored tanks. It could then be argued that this (within 10%) would be sufficiently close to meeting the DBE criteria that no further action would be necessary. This could be argued because the analyses are only accurate to about 10%, and there would still be conservatisms built into the analyses. As another alternative, the report agreed with Reference 16 that a more rigorous, nonlinear analysis could be performed which would probably show the tanks to be in compliance with the DBE criteria.

In summary, the cast-in-place octagonal vaults have been shown to meet DBE seismic criteria (Reference 14). The unanchored tanks also meet the DBE criteria (References 16 and 17). The square 2x2 vault could probably be shown to meet the DBE criteria if a definitive analysis were to be done (Reference 13). The anchored tanks could also probably be shown to meet the DBE criteria if a definitive analysis were to be done (References 16 and 17). The pillar and panel tank vaults probably could not be shown to meet the DBE criteria, but even so they would not be expected to fail catastrophically (collapse) during a DBE (Reference 15).

4.5 International Technology Corporation Assessment

In 1990, International Technology Corporation (ITC) was contracted to do an assessment of the Tank Farm per 40 CFR 265.191. Their study required several months and resulted in a 400-page report.

The report (Reference 18) assessed the fitness for use of the eleven stainless-steel tanks in accordance with the minimum criteria of 40 CFR 265.191. This tank assessment specifically excluded other tank systems and ancillary equipment facilities at the INTEC. These minimum criteria include (1) design standards used for tank construction; (2) hazardous characteristics of the waste stored or handled; (3) corrosion protection; (4) tank age; and (5) for non-enterable tanks, the results of a leak test accounting for temperature, tank deflection, vapor pockets, and a high groundwater table. The ITC findings, taken from the report (Pages ES-1 to ES-4 and Table 4-1), are quoted below:

> Design Standards Used for Tank Construction
>
> There is adequate documentation for the design and construction of Tanks WM-182 through WM-190 for compliance to the minimum requirements. The current documentation for WM-180 and WM-181, which are the oldest tanks, is inadequate in establishing the design standards to which these tanks were constructed.
>
> Hazardous Waste Characteristics
>
> The chemical and radiochemical composition of the wastes is derived from nuclear fuel dissolution processes at the INTEC. The dominant components of the non-zirconium waste types are aluminum and nitrate, and the dominant components of the zirconium waste types are aluminum, zirconium, fluoride and nitrate. All of the first-cycle raffinates[22] are acidic with hydrogen ion concentrations usually ranging from 1 to 3 molar and with radioactivity levels normally varying from 5 to 40 Ci/gal[23] for the Cs-137, Cs-134, Ce-144, and Sr-90 radionuclides. The wastes are classified as "hazardous" as defined by RCRA for two reasons. First is the presence of cadmium, lead, chromium, and mercury, which are included in the list of toxic constituents under the toxicity characteristic rule[24]. The second is due to corrosivity (low pH)[25].
>
> Corrosion Protection
>
> The corrosion control for the tanks is provided by the appropriate construction materials, and confirmed by a corrosion-coupon evaluation program. No active protection mechanism such as cathodic protection[26] is provided. The materials used in the Tank Farm and the liquid transfer system are 304L, 316L, and 347 stainless steels. The general corrosion[27] metal loss, as evidenced by the low corrosion rates on corrosion coupons

[22] Raffinate is the major liquid waste stream produced during fuel reprocessing.

[23] Measurements indicate that wastes with activities in excess of 80 Ci/gal were stored in the early years when concentrated short-cooled aluminum fuels were being processed.

[24] As identified in Section 2.2, liquid wastes in the tanks are currently being sampled for RCRA characterization to determine the applicable characteristic waste numbers.

[25] Listed hazardous waste numbers have been identified for the INTEC liquid waste systems (Reference 19). These numbers also apply to the liquid wastes stored in the tanks.

[26] A cathodic protection system is not relevent because the tanks are in a vault, not directly buried in contact with the soil.

[27] The term "general corrosion" used by ITC is equivalent to "uniform corrosion" as used elsewhere in this report.

recovered above the solids layer in the tanks, is well within the design limits of the tanks. There is evidence of solid particulates at the bottom of the storage tanks. The solids have been found by video inspection and consist of a finely graded, easily resuspended material. Over time, these solids settle to the bottom of the tank. There is also a possibility that solids exist in the waste transfer system. No information is currently available on the size, shape, chemical composition, grit size, specific gravity nor radioactive levels of the solids layer. Since the coupons have not been in the solids layer until recently, no information is available on the effect of these solids on corrosion rates. Additional testing and monitoring will be required to determine the significance of the solids on short- or long-term corrosion rates in the Tank Farm tanks and transfer piping system.[28]

As discussed by Zimmerman (1989, Reference 7), the observed general corrosion-rate data and physical examinations do not eliminate the possibility of localized attack in the tanks. Localized corrosion includes pitting, stress corrosion cracking (SCC), and embrittlement. No direct evidence of intergranular corrosion attack has been noted in corrosion coupons recovered above the solids layer from the tanks. Nevertheless, combinations of low temperature, altered solution chemistries in the solids layer, and notably extended periods of time will result in the progressive evolution of staining, pitting, and cracking. In addition, possible staining in WM-187 was observed during the tank washings as brownish stains on the plate portions of the tanks, away from the welds, which could not be removed by repeated attempts of the pressure hose. An evaluation was made based upon available information to determine if the passivation layer was sufficient to protect the tanks from localized corrosion. While the major problem is associated with the unknown effects of the solids layer, current indications are that some localized corrosion may exist.[29] Consequently, it was concluded that the existing corrosion protection does not meet the requirements of 40 CFR 265.191.

Tank Age

The ages of the tanks are known.

Leak Tightness

Because of the radioactive nature of the waste stored in the tanks, it is impractical to perform a mechanical leak test of the tanks using conventional methods of pressurization.

[28] The information in this paragraph reflects the status in 1990. Solids samples have been taken directly from the tanks and from wastes transferred to the Calciner. Corrosion coupons that monitor the tank bottoms were installed in all of the tanks by 1988. These coupons have now had 11 years exposure. When these coupons are removed from the tanks and analyzed, this will supply the "additional testing and monitoring" called for by ITC. The first of these coupon retrievals is reported in Section 4.8.

[29] There is significant disagreement with ITC's concern about localized corrosion based on the "possible staining" observed in Tank WM-187. The video was not of sufficient quality to make a clear determination. INTEC reviewers of the video think the "stains" could just be grinder marks left over from construction or residual solids on the wall. The Tank WM-188 inspection videos taken by the Light Duty Utility Arm in 1999 are of significantly higher quality than those obtained in the past. The evaluation of these videos has concluded that the wall surfaces and welds are in good condition with no visual evidence of localized corrosion attack. Tank WM-187 has experienced much the same history as Tank WM-188 and similar corrosion is expected in both tanks.

Visual inspection is also impossible.[30] Therefore, the leak tightness requirements of the regulation had to be inferred based on available liquid-level instrumentation data combined with an analysis of the sensitivity and potential errors associated with instrumentation. The major sources of error include fluctuations in temperature while the effects of tank-end deflection and evaporation losses were found to be insignificant. The depth to the groundwater at the INTEC is at least 400 feet, and water table effects in masking leakage rates are nonexistent. The leak tightness in each of the eleven tanks is continuously monitored by a series of precision, stainless steel radio frequency probes. The probes are capable of measuring fluid level changes within the tank to a resolution of .05 inch over probe lengths of from 40 to 50 feet.

Analyses of the probe data have been performed. They suggest that the fluctuations in tank volumes are due to thermal effects, and not due to tank leakage. Within the accuracy of instrumentation, the evaluations of current fluid levels for Tanks WM-180 through WM-189 indicate that leakage rates do not exceed 0.1 gallons per hour[31], and that the tanks are performing well which is in accord with their operational histories. There is no current or previous indication of unexplained loss of fluid from these tanks. Radiation monitoring has been performed in shallow wells around the tank farm. However, in view of sampling problems, the degree to which the radiation monitoring near the base of the tank is representative is not known.

Leak integrity of the tanks has been evaluated based on the current waste volumes and conditions. The tanks have leak integrity for the present storage of the high-level radioactive wastes provided that additional sampling of the thermal expansion properties of the fluids are made. Routine monitoring of the soon-to-be-implemented pressure transducer system[32] will provide additional information. It is important to note that the leak integrity examination did not consider filling the tanks to capacity although several of the tanks were nearly full. For those tanks at less than full capacity, it is especially important to monitor performance if fluid levels are raised causing an increase in bottom pressures to occur.

The results are as follows (Table 5):

[30] Visual inspection is difficult, but not "impossible". Cameras have been put into the tanks on several occasions. There is only limited access to the vault area to inspect the exterior of the tanks.

[31] This was the diminimus value selected by ITC for their studies. No actual leakage was indicated or detected.

[32] The transducers mentioned were installed and have functioned reliably for years.

TABLE 5. Summary Of Tank Assessment Compliance With Minimum Requirements.

	TANKS WM-180-181	TANKS WM-182-190	ANCILLARY EQUIPMENT
Design Standards	No	Yes	ND*
Hazardous Waste Characteristics	Yes	Yes	Yes
Existing Corrosion Protection			
General	Yes	Yes	Yes
Localized	ND	No	ND
Solids Layer	No	No	No
Age	Yes	Yes	Yes
Leak Test	ND	Yes	No[33]

*ND=Not determined on the basis of not meeting other criteria.

In summary, ITC did not certify the tanks as meeting all of the 40 CFR 265.191 criteria. However, their concerns for Tanks WM-182 through WM-190 were only on localized corrosion and corrosion in the solids layer on the bottom of the tanks. The localized corrosion concern was due to a stain observed on the wall of Tank WM-187 (in a video recording) that they felt could be a precursor to corrosion. The concern on corrosion in the solids layer was simply because no data were available at that time from corrosion coupons which had exposure in the solids layer.

4.6 Long-Term Plan for Tank Inspection and Corrosion Coupon Evaluation

An active program to monitor the materials performance of the tanks has been in place since Tank Farm operations began. The program originally consisted of (a) laboratory studies to evaluate the corrosion resistance compatibility of the materials of construction with the stored liquid wastes, (b) occasional visual inspections, and (c) the use of corrosion coupons. The most authoritative data pertaining to the materials performance of the tanks are obtained from evaluation of the corrosion coupons exposed to the actual liquid wastes stored in the tanks at approximately 10-year intervals. The last coupon evaluation for all of the tanks occurred in 1987-88, so it is time for another corrosion coupon evaluation. The Second Modification to the NONCO calls for submitting a closure plan for one of the pillar and panel vaulted tanks (WM-182 through WM-186) by December 31, 2000. It also calls for cease use of these tanks by June 30, 2003. Since the cease use and closure activities will include coupon evaluation and tank

[33] This "No" should actually be "ND" since ITC did not evaluate any ancillary equipment leak test data.

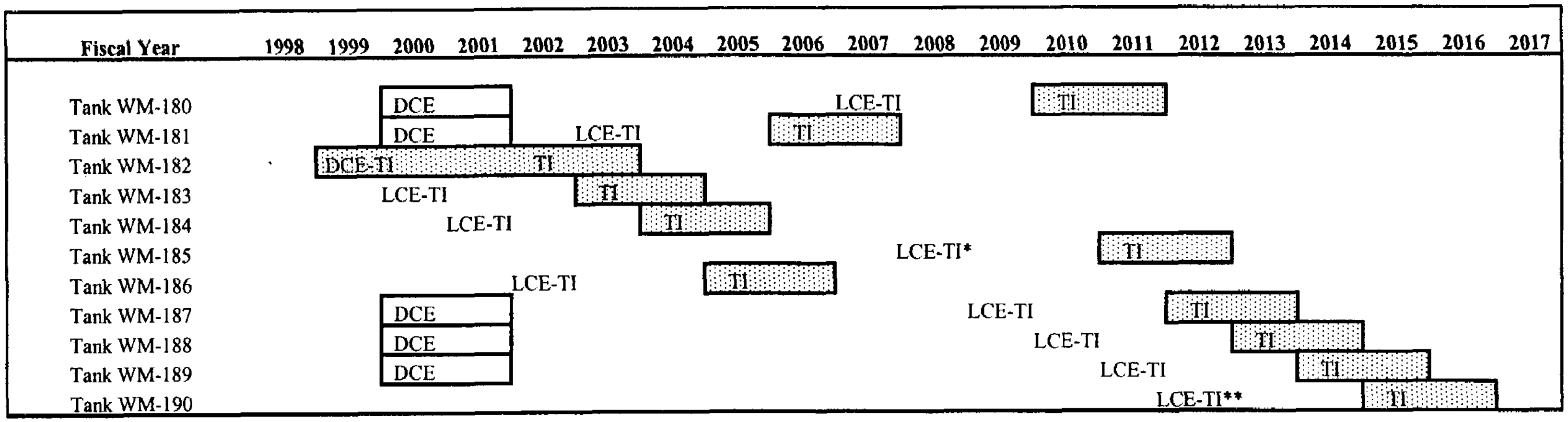
inspection activities, it is prudent to integrate the periodic coupon evaluation with the closure activities for the pillar and panel vaulted tanks.

Beginning in FY-1999, the initial plans were developed for tank closure. This preliminary schedule is shown in Table 6. The blocked-out years show the duration of actual closure activities for each tank. The closure time for Tank WM-182 is extended since it is the first tank that will be done and significant development of methods is required. This development will not need to be repeated for the remaining tanks, so all additional schedules are only two years for each tank. As part of the closure activities, two tank inspections will be made for each tank. The first will occur three years ahead of actual closure activities and the second will occur during the first year of closure as shown in Table 6. The first inspection will also include removing the corrosion coupons from the tank and evaluating them for corrosion to the extent that the data will be useful for future activities. For example, the coupons from the bottoms of at least three of the tanks will be carefully evaluated, since these data have not been available previously. However, the coupons which were exposed to the liquid waste solutions at higher levels will not receive a detailed evaluation unless the data are determined to be needed for tank closure or are determined to be valuable for long-term materials performance for other applications. The coupons will usually not be reinstalled since the tank risers, where the coupons are normally installed, are required for subsequent inspection and washing activities. In addition, there is little corrosion concern from this time forward until closure since the tank will be empty except for the heel. The heel will be extensively diluted during tank washing and flushing activities, thereby becoming less and less corrosive to the tank. The coupons will be reinstalled in all cases where continued waste storage is planned.

Since the non-pillar and panel vaulted tanks (WM-180, -181, -187, -188, -189, and -190) will remain in service for several more years before closure activities begin, additional corrosion coupon evaluations are needed. A portion of the corrosion coupons will be removed from the tanks and evaluated beginning in FY-2000 as shown on Table 6; the remaining coupons will be returned to service in their respective tanks. Since the Light Duty Utility Arm (LDUA) will be fully committed to performing the tank inspections and sampling activities in support of closure, inspections of the non-pillar and panel tanks, prior to the inspections for closure, will not be possible. The corrosion coupons in WM-190 will not be evaluated in 2000 since it has not been used to store waste; they will be evaluated in 2012 only if the tank has been put into service.

The schedules shown for inspection and closure of the pillar and panel vaulted tanks are independent of the outcome of the EIS since emptying these tanks depends only on operation of the HLLWE and should proceed according to the timelines shown in Table 6. The schedules shown for closure of the non-pillar and panel tanks are subject to the outcome of the EIS since they will be emptied by the process selected by the EIS. As a result, the inspection and closure schedule for these tanks may be modified. In any case, corrosion coupon evaluations will be done for the tanks remaining in operation by the 2011 timeframe to maintain the 10-year evaluation practice.

Table 6. Tank Farm Coupon Evaluation, Tank Inspection, and Closure Schedule.



Closure activities =

DCE = Detailed corrosion coupon evaluation

TI = Internal tank inspection

LCE-TI = Limited corrosion coupon evaluation and internal tank inspection

*If Tank WM-185 is selected to serve as an emergency spare tank, a coupon evaluation and/or tank inspection may be required at an earlier date.

**If Tank WM-190 is not used to store waste, the coupon evaluation and/or tank inspection is optional.

4.7 Corrosion Evaluation of Visual Data from Tank WM-188

Fabrication of High Level Waste Tanks

To understand the images captured from the video inspection that are described in the next section, a review of the construction practices for these tanks is needed. The tanks were fabricated out of rolled stainless steel plates that were welded together. Figure 28 shows an early construction view of Tank WM-188. The tank bottom and one row of the wall shell course have been installed. The horizontal and vertical edges of the plates where they were welded together are an obvious feature. There are also support structures for work platforms welded to the tank wall. These supports were later removed. Figure 29 shows the process at a later stage with grinding marks visible on the metal surfaces of the first row of metal plates where the supports were removed. Figure 30 shows the installation of cooling coils in WM-187. All of the supports that were attached to the walls have been removed. Extensive grinding marks are evident on the tank walls.

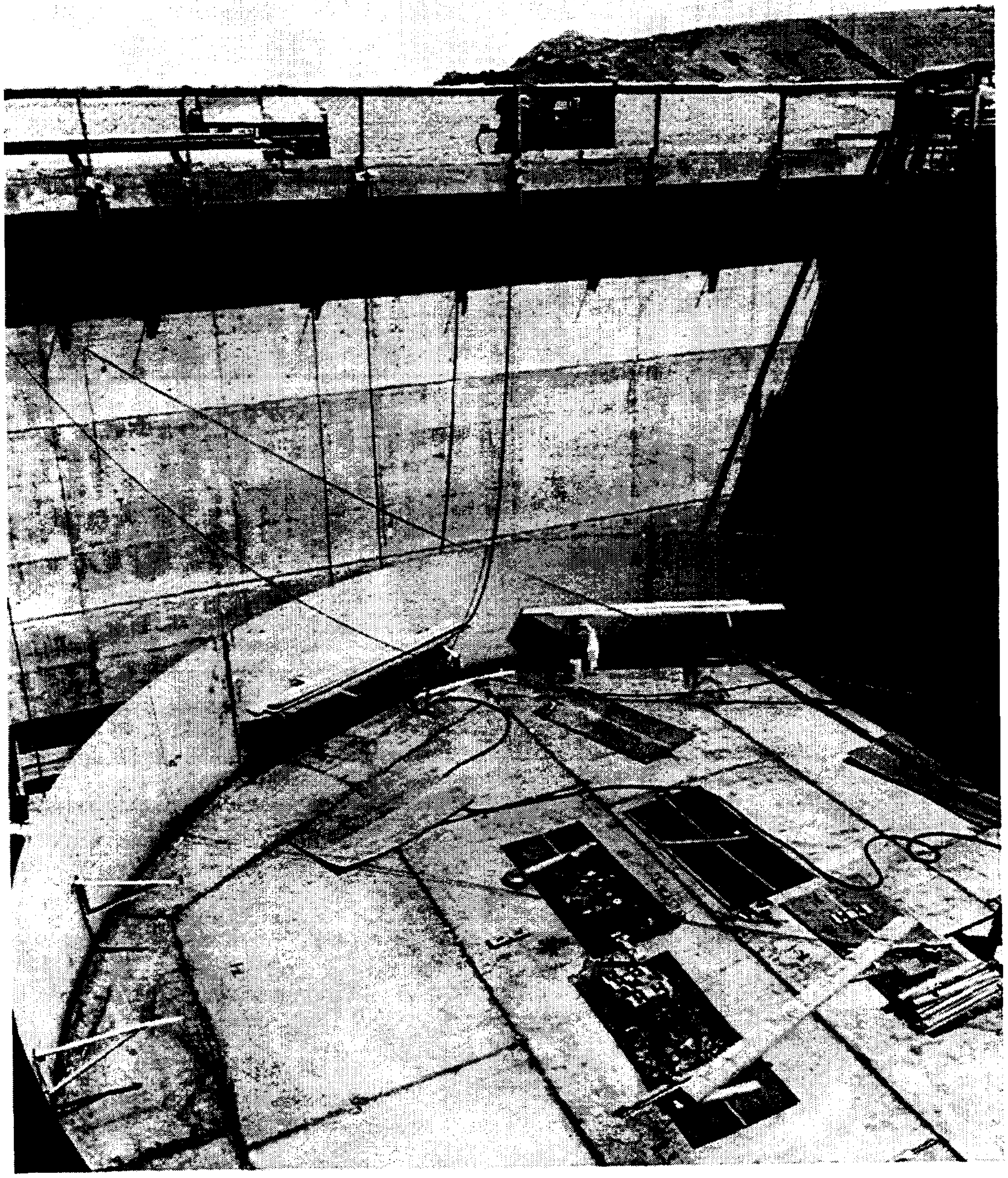


Figure 28. Tank WM-188 Erection

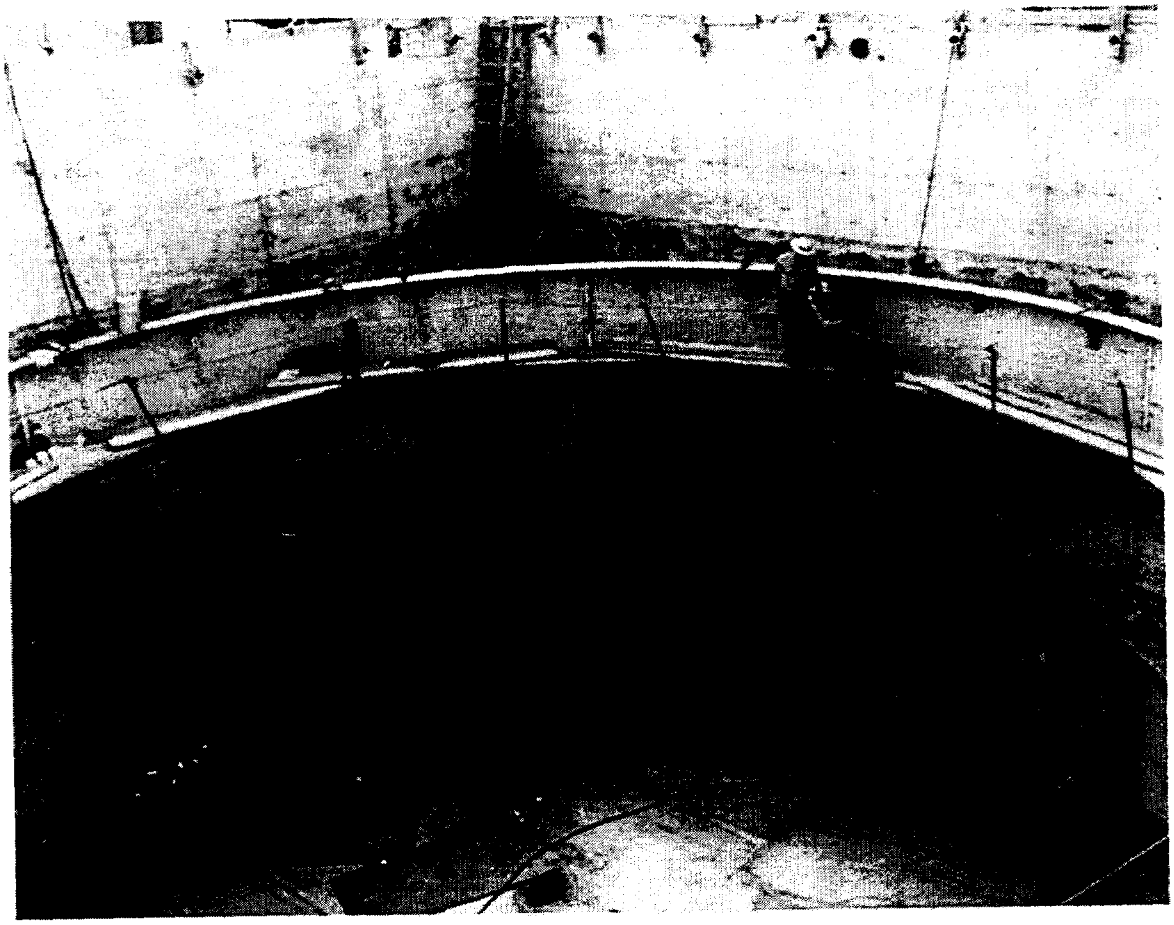


Figure 29. Tank WM-188 Tank Erection, Later Stages

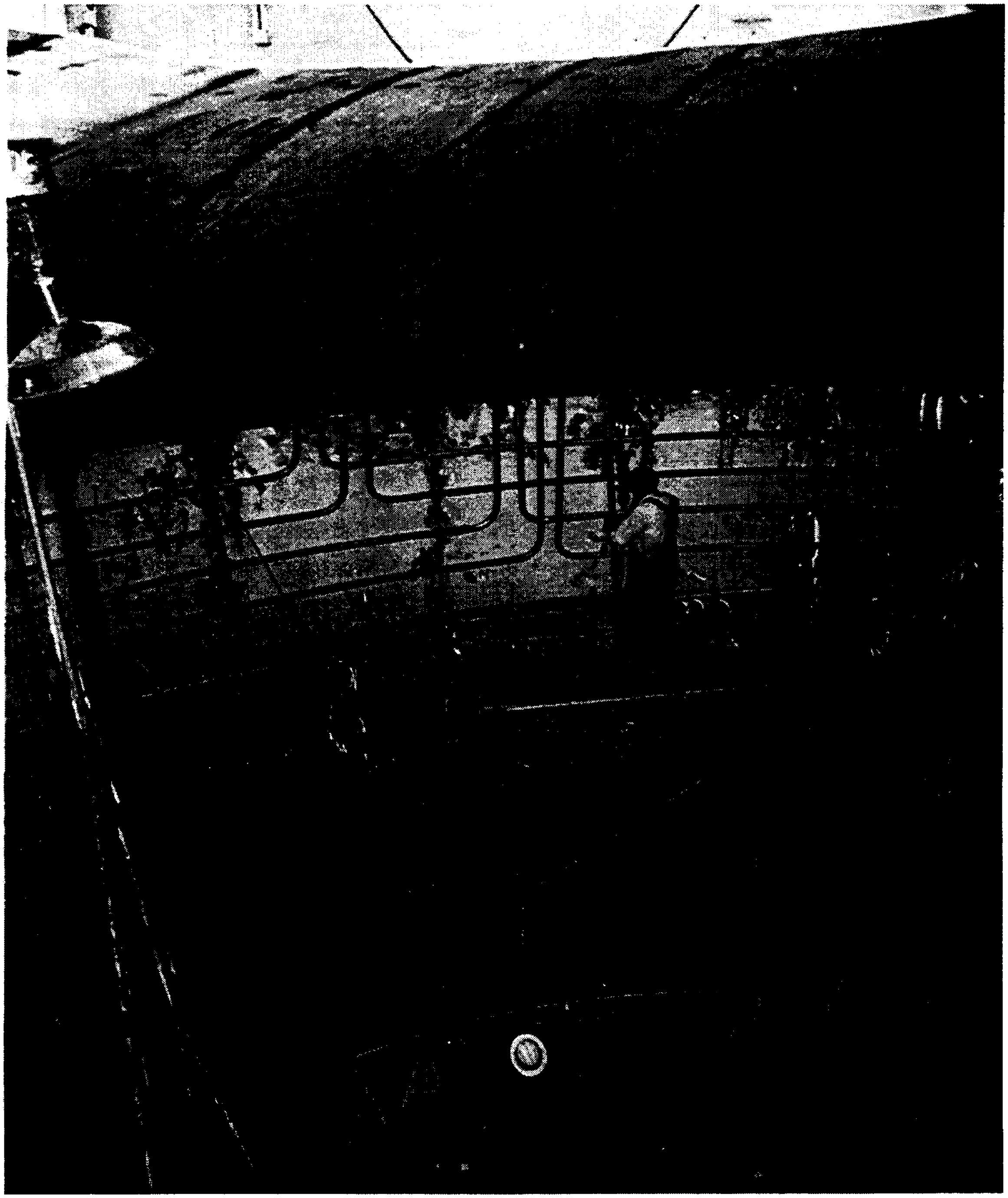


Figure 30. WM-187 Cooling Coils Installation

Corrosion Evaluation of WM-188 from LDUA Video

A video inspection system was deployed into WM-188 by the LDUA in February 1999. The inspection concentrated on accessible areas containing welds that are considered the most likely areas for the initiation of localized corrosion. The inspection technique was to scan the walls for visual evidence of localized corrosion as shown in the preceding pictures. A typical weld area is shown in Figure 31 that shows the intersection of two welds. This area would be exposed to high heat input from the intersecting welds that will increase susceptibility to intergranular corrosion. The weld joint area would also be an area of high residual tensile stress. There is no evidence of intergranular corrsion or cracking in the weld heat affected zone. There are black spots on the surface of the weld and base metal that appear to be surface deposits but this cannot be confirmed with a two-dimensional inspection technique. The shiny area to the left of the weld intersection appears to be a grinding mark from the original fabrication.

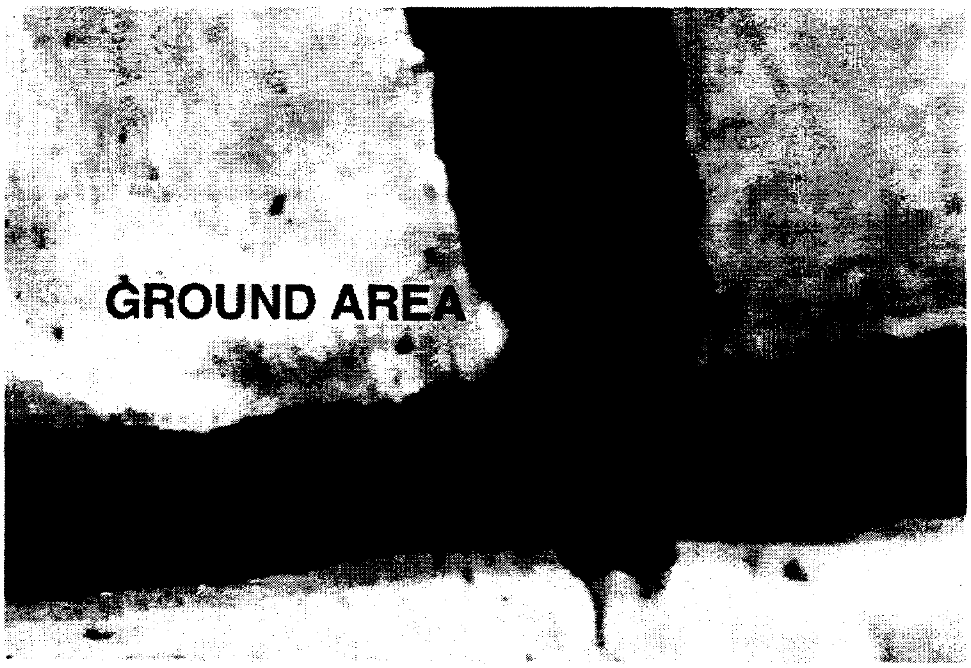


Figure 31. Weld Intersection in WM-188

Figure 32 shows a horizontal weld. There are indentations in the plate next to the weld. These are believed to be marks where a mechanical lifting device fastened to the plate as shown in Figure 33. There are other spots on the surface that cannot be measured for convexity or concavity.

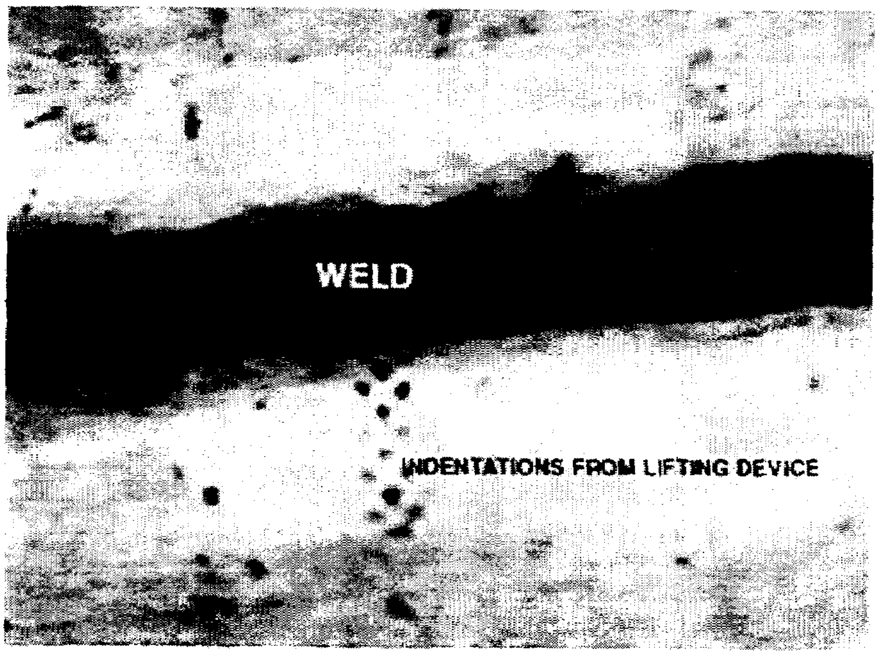


Figure 32. Areas of Mechanical Damage from Initial Tank Erection

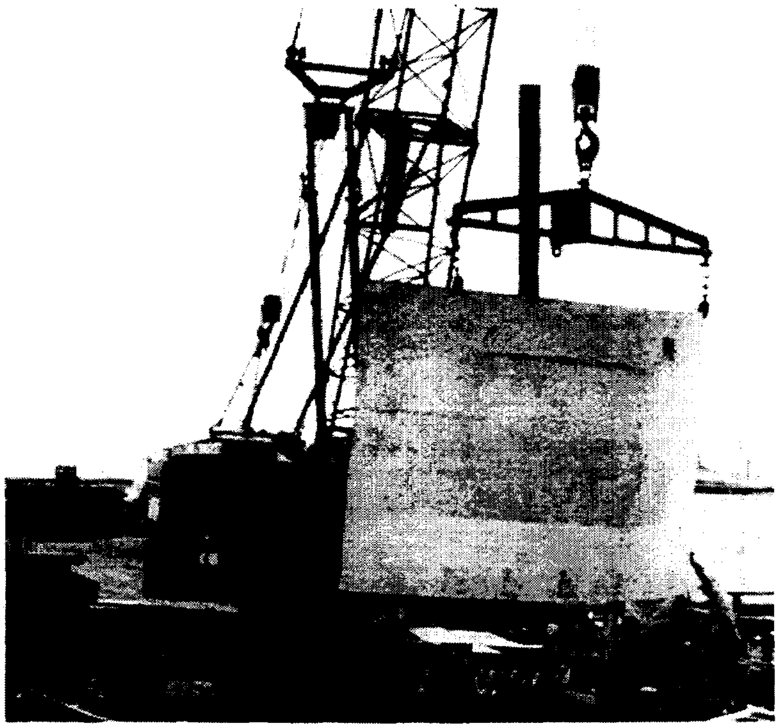


Figure 33. Lifting of Plate Section Showing Lifting Device

The tank walls and internal cooling coils of Tank WM-188 were covered with surface deposits as shown in Figure 34. The first deposit shows up as a lighter tone of gray in the video. It covers much, but not all of the top surfaces of the stainless steel cooling coils. There is a second type of black deposit that appears on top of all surfaces in the tank as shown in Figure 34. There is no evidence of crevice corrosion of the pipe surface or weld from these deposits. The weld appears to have the proper crown and there is no evidence of a higher corrosion rate for the weld or the weld heat affected zone.

Figure 34. Cooling Coil Pipe Surface with Deposits

In summary, a review of the video from the LDUA inspection of WM-188 shows no evidence of localized corrosion of the 304L stainless steel tank walls, welds, or weld heat affected zones. Areas of localized mechanical damage from the initial construction of this tank did not act as localized corrosion initiation sites. There were deposits of material on the tank walls, but there were no apparent areas of corrosion associated with these.

The video shows what appears to be a film-like deposit with suspended solids just below the surface of the liquid heel. This phenomenon has not been observed in the other tank inspections. The composition of this material and its significance to corrosion has not been determined. Further evaluation of the video and the chemistry existing in this heel will be required to resolve this question.

There are areas in which the two-dimensional video image could not be interpreted as to whether it was convex or concave. Additional development work should be performed to allow deployment of the Nondestructive Examination End Effector that will allow additional image characterization.

Based on the examination of the Tank WM-188 inspection video, it is concluded that the internal wall surfaces and welds of tank WM-188 are in good condition with no visible evidence of localized corrosion.

4.8 Corrosion Coupon Data from Tank WM-182

The INTEC Tank Farm consists of eleven vaulted 300,000-gallon underground tanks including Tank WM-182. Tank WM-182 was put into service in 1955, has been filled four times, and has contained aluminum and zirconium fuel reprocessing wastes as well as sodium bearing waste (Figure B-3).

A program to monitor corrosion in the waste tanks was initiated in 1953 when the first of the eleven Tank Farm tanks was placed in service. Corrosion coupons have been retrieved from the tanks and analyzed four times in the past: in 1962, 1976, 1983, and 1988. In 1988, new corrosion coupon assemblies were added to the tanks, including WM-182, to monitor the conditions on the tank bottom. In 1999, the remaining 45 corrosion coupons were retrieved from Tank WM-182 and analyzed per ASTM G 1-90 (Reference 3) and ASTM G 46-94 (Reapproved 1999), "Standard Guide for Examination and Evaluation of Pitting Corrosion" (Reference 21). These corrosion coupons consisted of 40 sections of extruded seamless Type 304L stainless steel pipe and 5 welded and machined Type 304L plate type samples. The results from the analysis are provided in Table 7. Details of the analysis are provided in Reference 22.

Physical examination of the welded corrosion test coupons exposed to the tank bottom conditions of Tank WM-182 revealed very light uniform corrosion (Figure 35). Although there was concern that the solids on the tank bottom could promote corrosion (see the International Technology Assessment in Section 4.5), the measured corrosion rates on the tank bottom were significantly less than the rates higher in the tank. There was no evidence of localized corrosion on the tank bottom coupons. It should be noted that the corrosion was so benign on the pictured coupon that the edge of the coupon can still reflect the wording on the paper even after more than eleven years of exposure to waste solutions and solids.

Examination of the external surfaces of the seamless pipe samples, which were suspended above the tank bottom, showed very light uniform corrosion with slight indications of possible pit initiation parallel to the extrusion direction of the seamless pipe and start of end grain corrosion of the cut edges (Figures 36 and 37). The end grain effects are not seen on the tank walls because the cut edges of the metal plates are welded together. The weld, not the cut edge, is then exposed to the tank environment. There is no evidence of pit initiation on any other corrosion coupons from any other waste tanks. These indications were only evident when examined under a stereo microscope at magnifications of 20X and above. Visual examination of the coupon support cables, where they were not encased in plastic, failed to reveal any indication of liquid-vapor or liquid-liquid interface corrosion or any crevice corrosion corrosion.

Based on the WM-182 coupon evaluations, which have occurred throughout the life of the tank, the metal loss from the tank wall is not expected to exceed 0.55 mil (0.00055 inch). For purposes of waste storage, this is a negligible amount of metal loss (approximately one percent) from the 50-mil corrosion allowance. Significant localized corrosion such as pitting or heat affected weld zone attack was not detected on the corrosion coupons and is not expected to be a materials problem in the tank.

TABLE 7. Corrosion Data For Coupons Retrieved From Waste Storage Tank WM-182 In 1999.

Initial Tank Service Date	Tank Construction Material (SS)	Tank Service (Years)	Coupon Exposure (Years)	Exposure Level (Inches)	Average Uniform Corrosion Rate (mpy)	Average Indicated Metal Loss from Tank Internal Surface (mil)	Maximum Uniform Corrosion Rate Observed (mpy)	Metal Loss from Tank Based on Maximum Corrosion Rate (mil)
May 1955	Type 304L	44.4	-------	--------	---------	------------	1.24×10^{-2} (72")	5.5×10^{-1}
			11.4	0	3.5×10^{-4}	1.6×10^{-2}	5.3×10^{-4}	---------
			30.5	18	8.6×10^{-3}	3.8×10^{-1}	9.0×10^{-3}	---------
			28.3	36	1.1×10^{-2}	4.9×10^{-1}	1.1×10^{-2}	---------
			26.5	72	1.2×10^{-2}	5.1×10^{-1}	1.2×10^{-2}	---------

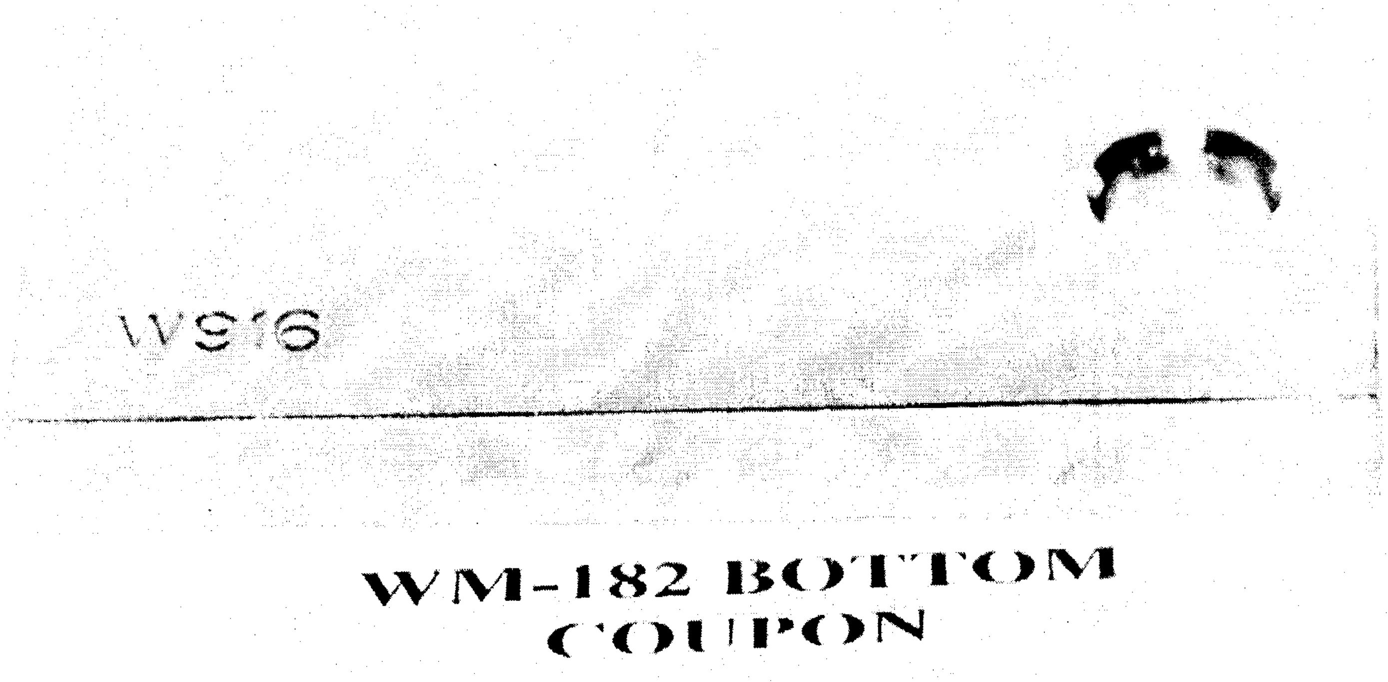


Figure 35. Coupon Retrieved from the Bottom of Tank WM-182 in 1999
(Actual size 3 inches x 1.5 inches x 0.25 inch thick)

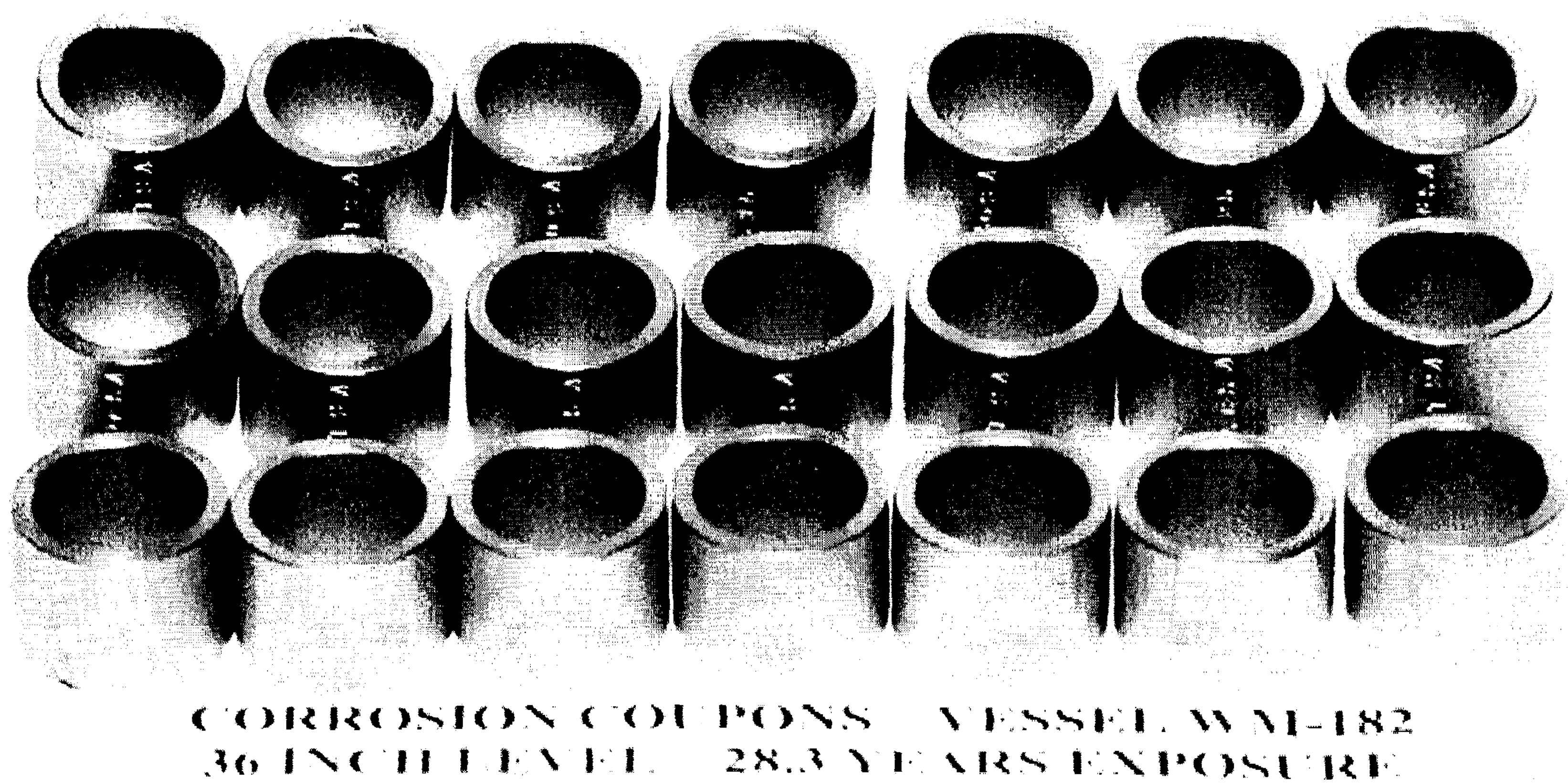


Figure 36. Coupons Retrieved from the 36-inch Level of Tank WM-182 in 1999
(Coupons made from 1-inch Sch 40 pipe)

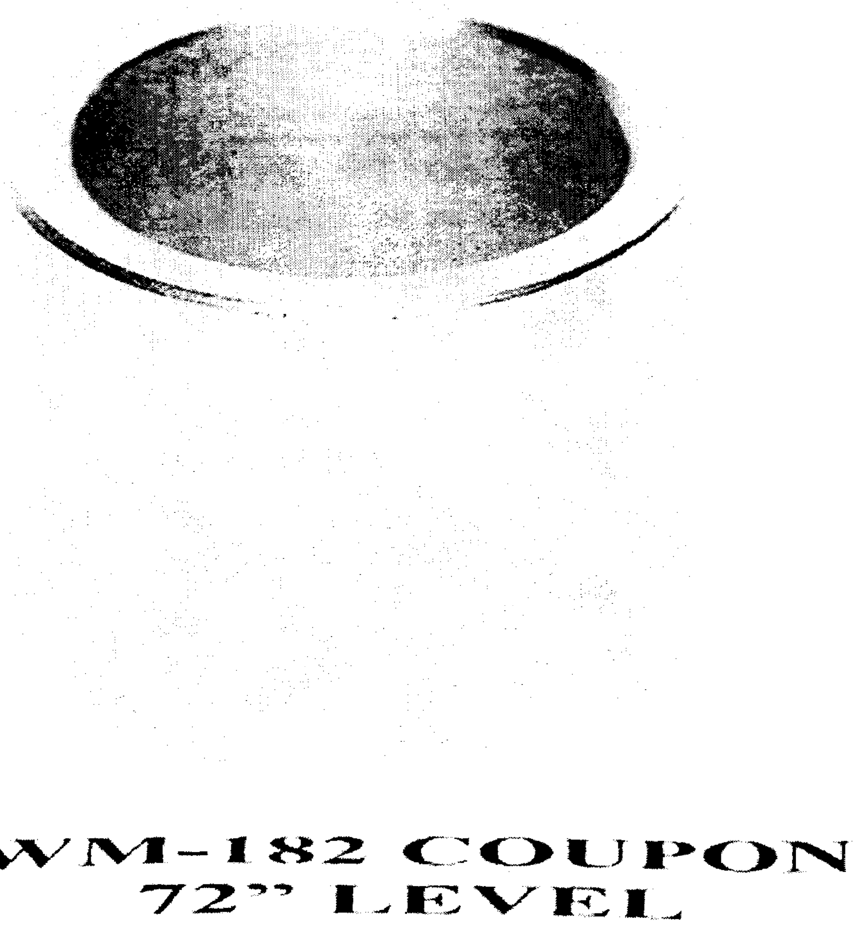


Figure 37. Coupon Retrieved from the 72-inch Level of Tank WM-182 in 1999
(Coupon approximately 1.3 inches outside diameter and one inch long)

5. ESTIMATED TANK AND ANCILLARY EQUIPMENT LIFE

The tanks were originally designed with a corrosion allowance, but no design life was specified. Occasionally a misstatement is made that the design life has been exceeded, since the normal design life for many nuclear facilities is 20-30 years. This is not the case for the INTEC waste storage tanks. In fact, a FLUOR Corporation report (Reference 20) states: "The objective of this study is to determine the most economical method of storing the waste products from processing zirconium-uranium alloy fuel elements. The waste must be stored for 300-400 years; however, individual tanks must serve for at least 50 years without leakage". This indicates the thinking in 1959 was that the tanks planned for storing zirconium type wastes should be designed so that they could serve reliably for at least 50 years, when storing this relatively corrosive waste.

Since there is no specified design life, one way to calculate a reasonable tank life is to determine the corrosion rate for the tank material under actual operating conditions. As described earlier, corrosion coupons have been in the tanks throughout their operating lifetimes. These coupons have been retrieved from the tanks and analyzed on approximately ten-year intervals. The results have been routinely reported (References 7-10). Reference 7 provides an excellent overview of the corrosion status of all eleven tanks in 1988. It's abstract states:

> "Corrosion test coupons removed from the high level liquid waste (HLLW) tanks at the Idaho Chemical Processing Plant (ICPP) during a 1987-1988 coupon recovery operation have been evaluated. The data indicate that the fluoride-containing first-cycle raffinates[34] (zirconium waste) are the most corrosive solutions with an average uniform corrosion rate of 2.9×10^{-2} mil per year. The average general corrosion[35] rate for non-zirconium first-cycle waste solution is 1.3×10^{-2} mil per year. Sodium bearing wastes (principally PEW Evaporator bottoms) are much less corrosive with an average general corrosion rate of 6.6×10^{-4} mil per year. These corrosion rates indicate very low uniform corrosion rate for the internal surfaces of the austenitic stainless steel tanks. The corrosion test coupons in the HLLW vessels at this time do not indicate any localized corrosion such as pitting or heat affected weld zone attack. New coupon assemblies were installed in the waste tanks which will be exposed on the bottom of most tanks."

The 300,000-gallon waste tanks were constructed from 1951 to 1964 and were put into radioactive service from 1953 to 1966. The latest study (Reference 7), conducted in 1989 using data from corrosion coupons retrieved in 1987-88, shows that the tank which has been in the most corrosive service[36] has lost a total of 1.2 mils of metal over 23.3 years of service (corrosion rate of 5.3×10^{-2} mpy). The tanks were designed with a corrosion allowance of 125 mils. If the corrosion data were extrapolated based on this worst case corrosion rate, the tank life would be approximately 2400 years. It is important to note that this is only the time required to corrode

[34] Raffinate is the major liquid waste stream produced during fuel reprocessing.

[35] The term "general corrosion" used in Reference 7 is equivalent to "uniform corrosion" as used elsewhere in this report.

[36] This is Tank WM-188 which was examined by the LDUA in 1999.

away the corrosion allowance metal; leakage would still not occur until the corrosion allowance was exceeded and another subsequent event, such as an earthquake, then caused tank failure. Since the tanks were constructed, the DOE has put additional criteria related to seismic activity in place. The most recent seismic studies of Tank Farm tanks (References 16 and 17) established a corrosion allowance of 50 mils. If these highest rate corrosion data are extrapolated using these criteria, the remaining tank life is estimated at 970 years. However, these corrosion rates are for the more corrosive zirconium wastes that no longer exist in the Tank Farm. Since the only waste that will be stored in the future is SBW, the corrosion rates are likely to be significantly lower. Using the corrosion rates quoted above from Reference 7, the average uniform corrosion rate for SBW is 44 times less than for zirconium waste that substantially increases the estimated tank life. Of some concern is the possibility that changing waste compositions may induce accelerated localized corrosion due to pitting or stress cracking. Although this accelerated corrosion has not been detected on corrosion coupons during the 46-year history of waste storage at INTEC, continued monitoring of waste compositions and tank corrosion rates is required to assure the tanks remain leak free.

As discussed in Section 4.3, the corrosion rates in the ancillary equipment are expected to be significantly lower than the corrosion rates in the waste tanks due to the greatly reduced exposure time in the ancillary equipment. Therefore, on the basis of corrosion, the estimated life of the ancillary equipment is greater than the expected life of the tanks. The ancillary equipment is expected to continue to serve reliably for as long as the tanks are in service except for infrequent mechanical failures such as valve or flange leaks due to seal degradation.

These estimates are based on corrosion data collected through 1988 from coupons suspended in the waste solutions. However, these initial coupons did not monitor the tank bottoms on which precipitated solids may have accumulated. Additional new coupons were installed in 1987-88 specifically to monitor the tank bottoms. The first of these coupons were retrieved from Tank WM-182 and analyzed during 1999. The tank life estimates were not impacted by these new data since the effects of accumulated solids did not increase corrosion rates of the tank bottom. In fact the bottom corrosion rates were 100 times (5.3×10^{-4} vs. 5.3×10^{-2} mpy) lower than the maximum corrosion rates used for the tank life estimate. Visual examination methods using the LDUA in WM-188, the tank that stored the most corrosive waste solutions, also did not provide any additional information that would reduce the estimated tank life.

6. CONCLUSIONS

1. The evidence from visual and corrosion coupon evaluations shows light, uniform corrosion has occurred in all of the in-service waste tanks.

2. None of the waste tank corrosion data, either past or present, has shown any evidence of significant localized corrosion.

3. The low uniform corrosion rates and the lack of any indication of significant localized corrosion indicate that the passivation layer has effectively formed on the tanks' internal surfaces and has not been degraded under the waste storage conditions.

4. The coupons retrieved from Tank WM-182 in 1999 show that the tank has experienced light, uniform corrosion. There was no evidence of significant localized corrosion.

5. The coupons retrieved from the bottom of Tank WM-182 in 1999 exhibited the lowest measured corrosion rates of all coupons retrieved in 1999. There was no evidence of localized corrosion on the bottom coupons.

6. Based on the 1999 video inspection of Tank WM-188, the wall surfaces and welds are in good condition with no visible evidence of localized corrosion.

7. Based on the maximum measured corrosion rates, it is concluded that the estimated life of the 300,000-gallon tanks is significantly longer (970 years) than the time required for emptying and closing the tanks.[37]

8. Based on corrosion data obtained from the high level waste tanks and the operating history of the transfer lines, valves, jets, etc., the service life of the ancillary equipment in the INTEC Tank Farm is estimated to exceed that of the tanks.

[37] The current baseline plan calls for emptying the pillar and panel vaulted tanks by June 30, 2003 and the reminder of the 300,000-gallon tanks by December 31, 2012 as required by the Settlement Agreement and the NONCO. The current plans also call for RCRA closing the last tank in 2016. This means that none of the tanks would be required to hold liquid longer than 20 more years.

7. RECOMMENDATIONS

1. Retrieve and report laboratory corrosion test data already generated at INTEC on localized corrosion of stainless steel regarding pitting, stress corrosion cracking, and crevice corrosion in waste solutions containing chlorides, mercury, and nitrate. Determine the applicability of the data to the tank life estimates.

2. Start a corrosion test program to develop data for the new waste chemistries that will be stored in WM-187, -188, and -189. These data will be used to better predict the remaining life of these tanks.

3. Complete the development work on the Nondestructive Examination End Effector (NDE EE) and deploy the NDE EE on subsequent LDUA examinations to better quantify surface anomalies. The results of these inspections should be correlated with corrosion coupon measurements to better characterize surface anomalies found during the video inspections.

4. Resolve the issue of the film-like deposit with suspended solids just below the liquid surface observed in the WM-188 video.

8. REFERENCES

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APPENDIX A

TANK FARM WASTE CONCENTRATIONS

APPENDIX A

TANK FARM WASTE CONCENTRATIONS[38]

[38] The waste composition data shown here are from chemical analyses conducted to meet operational needs and do not meet the more rigorous requirements of RCRA. These analyses are based the latest analytical data available, but may not reflect recent changes in tank waste composition. For example, the recent additions of decontamination solutions to Tank WM-187 are not accounted for in the Appendix A data since samples have not yet been taken and analyzed. The current waste in Tank WM-187 is more dilute than shown in the Appendix A tables. Minor volume changes have occurred for some of the other tanks, but significant changes to the waste composition are not expected.

Table A1. Tank Farm Waste Chemical Concentrations.

WASTE TANK		WM-180	WM-181	WM-182	WM-183	WM-184	WM-185	WM-186	WM-187	WM-188	WM-189	WM-190
VOLUME	gal	278,600	275,900	6,400	30,900	262,600	20,600	281,500	61,200	13,500	100,900	500
DENSITY	g/ml	1.26	1.16	1.12	1.17	1.23	1.27	1.17	1.13	1.32	1.31	1.00
ACID (H^+)	M	1.19	1.73	0.49	1.01	1.76	1.71	1.43	1.78	2.73	2.57	0.02
NITRATE (NO_3)	M	4.74	3.55	1.69	2.66	4.20	5.24	3.11	3.03	6.16	6.23	0.02
ALUMINUM (Al)	M	0.61	0.22	0.26	0.36	0.54	0.74	0.28	0.32	0.85	0.92	
BORON (B)	M	0.011	0.017	0.004	0.008	<.014	0.037	<.014	<.0139	0.040	0.025	
CADMIUM (Cd)	M	0.0008	0.0053	0.0005	0.0008	<.005	0.001	<.005	<.005	0.0106	0.0051	
CALCIUM (Ca)	M	0.035	0.047		0.026	0.017	0.071	0.052	0.046	0.155	0.084	
CHLORIDE (Cl)	M	0.033	0.013	0.003	0.007	0.029	0.025	0.019	0.003	0.015	0.024	0.0003
CHROMIUM (Cr)	M	0.003	0.003	0.002	0.008	<.004	0.005	0.004	<.004	0.014	0.005	
FLUORIDE (F)	M	0.004	0.094	0.021	0.033	0.024	0.168	0.042	0.119	0.249	0.222	0.007
IRON (Fe)	M	0.018	0.012	0.011	0.031	0.015	0.025	0.016	0.013	0.056	0.025	
LEAD (Pb)	M	0.0013	0.0010	0.0004	0.0008	0.0003	0.0013	0.0004		0.0011	0.0010	
MANGANESE (Mn)	M		0.014		0.008		0.020			0.013		
MERCURY (Hg)	M	0.0010	0.0005	0.0006	0.0017	0.0007	0.0041	0.0010	0.0027	0.0077	0.0051	
MOLYBDENUM (Mo)	M		0.0005	0.0002	0.0009		0.0001	0.00002		0.0007	0.0001	
NICKEL (Ni)	M	0.0015	0.0012		0.0043	<.0044	0.0017			0.0054		
PHOSPHATE (PO_4)	M		0.006				0.003	0.0005		0.0003	0.0003	
POTASSIUM (K)	M	0.19	0.13	0.050	0.06	0.09	0.17	0.15	0.01	0.16	0.11	
SODIUM (Na)	M	2.07	0.91	0.52	0.50	1.35	1.25	0.88	0.12	0.85	0.90	
SULFATE (SO_4)	M	0.045	0.038	0.016	0.026	0.029	0.040	0.031	0.010	0.037	0.007	
ZIRCONIUM (Zr)	M	<0.0012	0.006	0.003	<0.001	<0.013	0.010		0.015	0.030	0.036	

Estimated as of Oct 1999

Information for WM-187 is the latest available. Approximately 35,000 gallons of flush solutions have been added.

Table A2. Tank Farm Waste Radionuclide Concentrations.

		WM-180	WM-181	WM-182	WM-183	WM-184	WM-185	WM-186	WM-187	WM-188	WM-189	WM-190
H 3	Ci/L	2.13E-05	1.91E-05	3.21E-04	2.66E-04	*4.20E-06*	3.24E-05	*6.27E-06*	*1.26E-05*	*8.44E-05*	3.39E-05	*2.56E-06*
Co 60	Ci/L	*2.77E-05*	9.43E-05	2.80E-05	7.94E-05	2.44E-05	3.01E-05	3.27E-05	*5.26E-05*	2.79E-04	2.99E-05	*1.07E-05*
Sr 90	Ci/L	2.21E-02	2.71E-02	5.28E-02	8.69E-02	1.17E-02	9.20E-02	2.11E-02	*5.11E-02*	2.72E-01	1.14E-01	*1.04E-04*
Ni 63	Ci/L	2.64E-05	6.14E-05	*3.07E-05*	*6.20E-05*	*9.89E-06*	*5.89E-05*	*1.47E-05*	*2.96E-05*	*1.99E-04*	*7.07E-05*	*6.02E-06*
Tc 99	Ci/L	*4.78E-06*	*4.23E-06*	*5.16E-06*	*1.26E-06*	*2.97E-06*	*1.77E-05*	*4.42E-06*	*8.88E-06*	1.04E-04	*2.12E-05*	*1.81E-06*
Ru 106	Ci/L	*5.07E-06*	1.70E-06	6.06E-06	*1.92E-05*	*3.21E-06*	5.09E-07	*4.79E-06*	*9.62E-06*	2.59E-07	*2.30E-05*	*1.96E-06*
Sb 125	Ci/L	*1.51E-05*	5.78E-05	*2.81E-05*	*5.89E-05*	*9.39E-06*	*5.60E-05*	1.99E-05	*2.81E-05*	*1.89E-04*	*6.72E-05*	*5.70E-06*
I 129	Ci/L	<1.4E-08	<3.3E-07	*4.88E-08*	*1.02E-07*	5.72E-06	1.05E-07	*2.43E-08*	*4.89E-08*	4.77E-09	*1.17E-07*	*9.90E-09*
Cs 134	Ci/L	5.02E-04	1.30E-04	2.56E-04	1.82E-04	7.50E-06	6.44E-05	5.31E-05	*6.22E-05*	6.82E-04	1.68E-04	5.45E-07
Cs137	Ci/L	2.74E-02	2.82E-02	5.29E-02	1.11E-01	1.74E-02	1.04E-01	2.60E-02	5.00E-02	3.59E-01	1.25E-01	1.02E-02
Ce 144	Ci/L	*7.00E-06*	3.82E-07	1.97E-06	6.55E-07	*4.45E-06*	3.82E-07	2.36E-07	*1.33E-05*	*8.90E-05*	*3.18E-05*	9.56E-12
Eu 154	Ci/L	4.85E-05	2.60E-04	2.72E-04	4.43E-04	3.25E-05	2.15E-04	1.08E-04	*1.92E-04*	1.59E-03	3.99E-04	2.55E-05
Eu 155	Ci/L	*1.29E-04*	7.34E-05	1.13E-04	2.41E-04	*8.16E-05*	4.86E-04	3.48E-05	*2.44E-04*	4.92E-04	*5.84E-04*	3.15E-06

Corrected to October 1999

Values in *Italics* are calculated assuming typical Sodium Bearing Waste distributions.

Information for WM-187 is the latest available. Approximately 35,000 gallons of flush solutions have been added.

Table A3. Tank Farm Waste Actinide Concentrations.

		WM-180	WM-181	WM-182	WM-183	WM-184	WM-185	WM-186	WM-187	WM-188	WM-189	WM-190
U 234	Ci/L	5.61E-07	8.53E-07	7.32E-07	3.39E-07	8.23E-07	1.31E-06	9.77E-07	3.16E-08	6.39E-07	7.88E-07	*1.25E-07*
U 235	Ci/L	1.54E-08	2.14E-08	2.12E-08	1.43E-08	2.26E-08	2.74E-08	2.27E-08	7.11E-10	2.59E-08	1.65E-08	*3.91E-09*
U 236	Ci/L	7.36E-09	7.56E-08	7.88E-08	1.39E-08	1.43E-08	6.09E-08	5.85E-08	3.18E-09	2.97E-08	3.82E-08	*6.17E-09*
U 238	Ci/L	9.37E-09	2.11E-08	3.99E-10	1.62E-08	9.16E-09	2.47E-08	5.15E-08	2.08E-12	2.77E-08	1.44E-08	*3.91E-09*
Np 237	Ci/L	4.34E-07	1.93E-07	8.00E-07	4.17E-07	4.60E-07	1.44E-05	2.90E-07	5.67E-07	1.61E-06	8.89E-06	*5.42E-07*
Pu 238	Ci/L	3.47E-04	6.15E-04	9.50E-04	3.56E-04	6.59E-04	8.39E-04	2.32E-04	1.99E-03	3.77E-03	2.25E-03	*7.23E-05*
Pu 239	Ci/L	5.65E-05	1.30E-05	1.06E-04	1.30E-04	8.30E-05	7.52E-05	3.99E-05	1.04E-05	2.39E-04	5.29E-05	*1.01E-05*
Pu 240	Ci/L	1.69E-05	3.65E-06	6.08E-06	1.02E-05	3.40E-05	2.05E-05	9.86E-06	2.34E-06	2.11E-05	1.40E-05	*1.96E-06*
Pu 241	Ci/L	2.92E-04	2.53E-04	2.08E-04	2.79E-04	4.11E-04	8.35E-04	1.61E-04	7.99E-04	1.75E-03	1.20E-03	*5.72E-05*
Pu 242	Ci/L	1.27E-08	8.63E-09	7.17E-09	2.98E-08	1.00E-08	2.44E-08	4.17E-09	5.93E-09	6.05E-08	1.94E-08	*1.48E-09*
Am 241	Ci/L	5.85E-04	2.31E-04	3.35E-04	5.56E-04	2.56E-04	6.32E-04	2.24E-04	5.28E-04	1.57E-03	8.36E-04	*9.03E-06*

Corrected to October 1999

Values in *Italics* are calculated assuming typical Sodium Bearing Waste distributions.

Information for WM-187 is the latest available. Approximately 35,000 gallons of flush solutions have been added.

APPENDIX B

HISTORICAL OPERATIONS OF THE TANK FARM

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HISTORICAL OPERATIONS OF THE TANK FARM

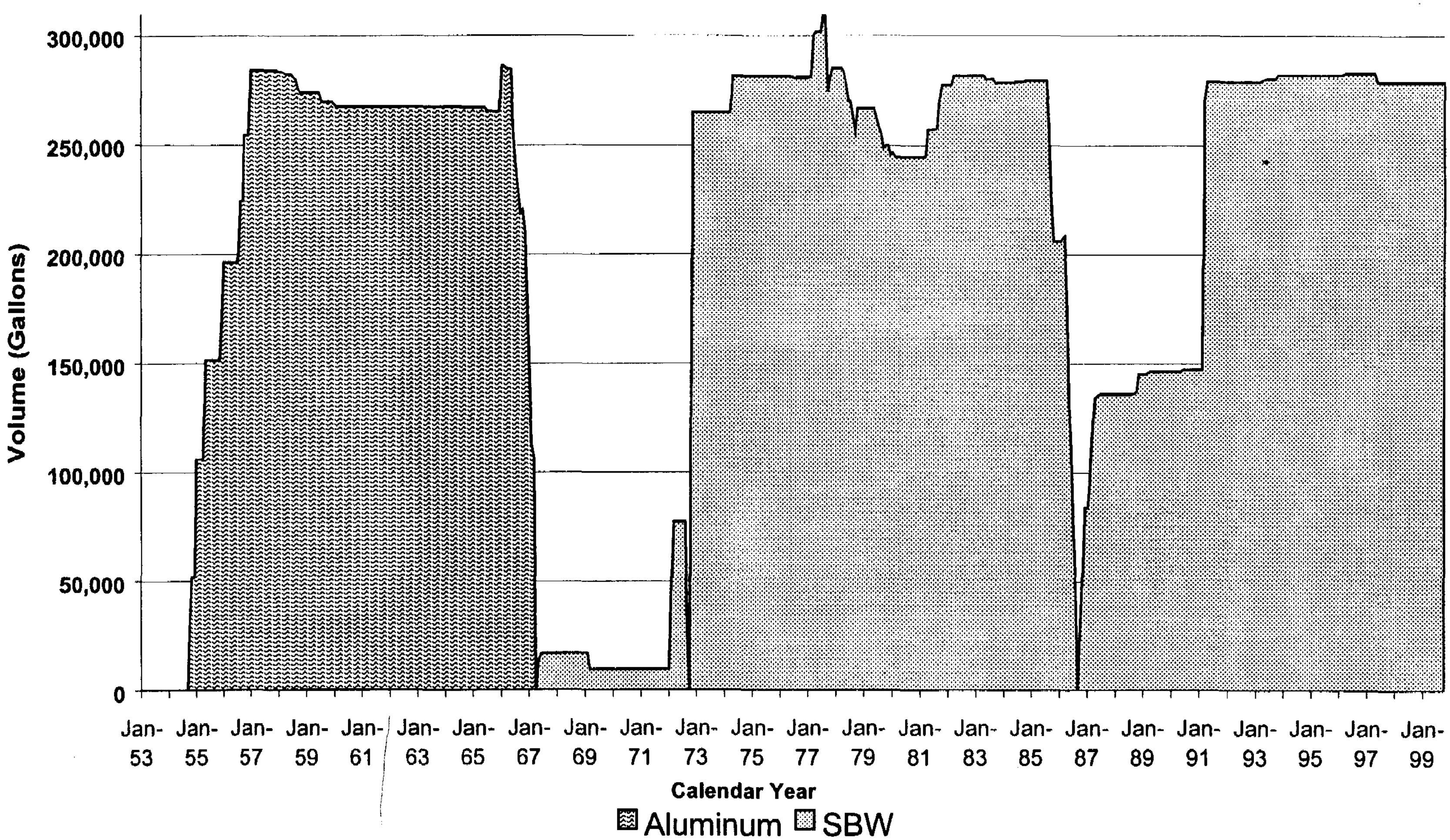

Figure B-1. Historical Operations of Waste Tank WM-180.

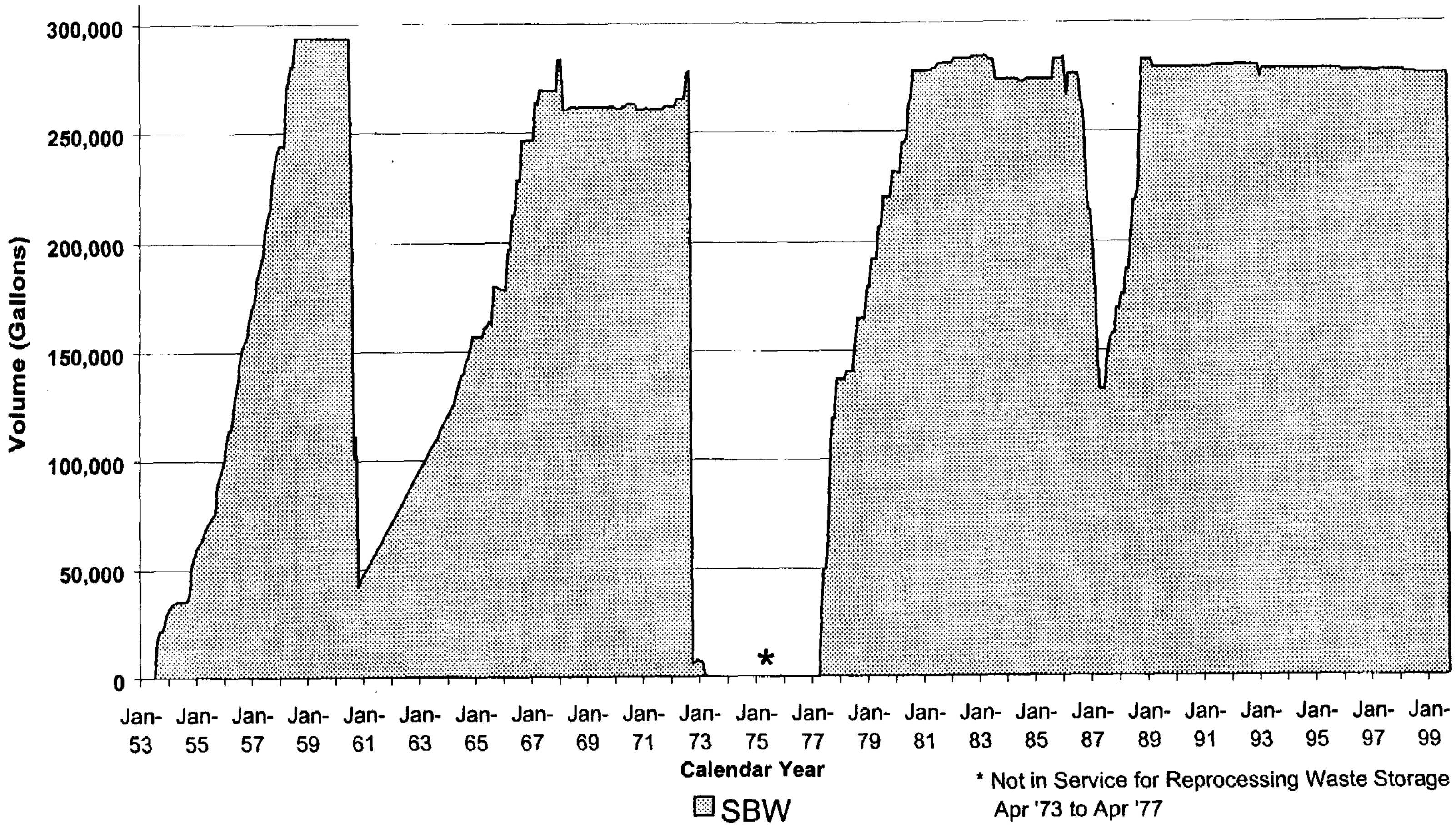

Figure B-2. Historical Operations of Waste Tank WM-181.

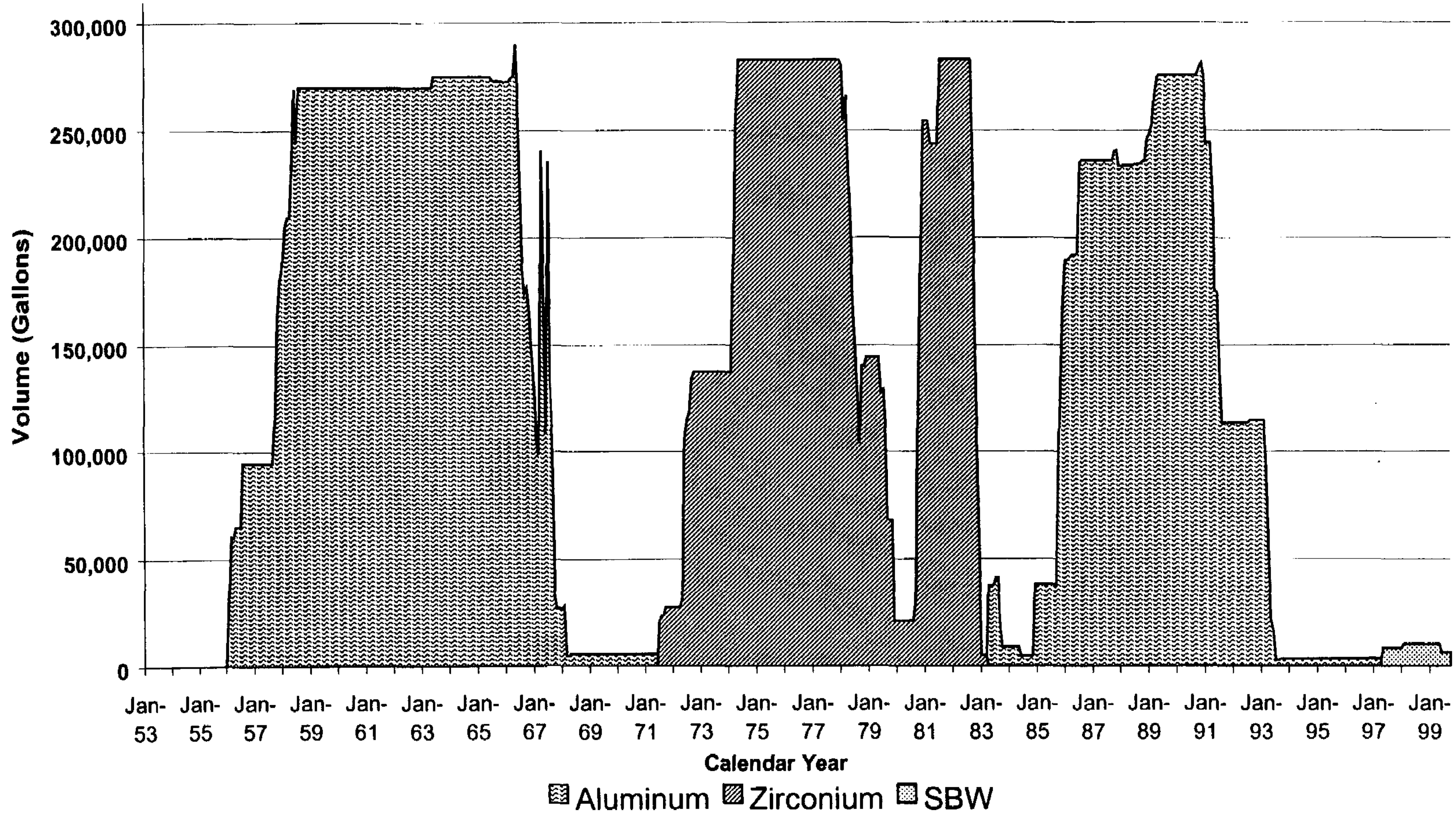

Figure B-3. Historical Operations of Waste Tank WM-182.

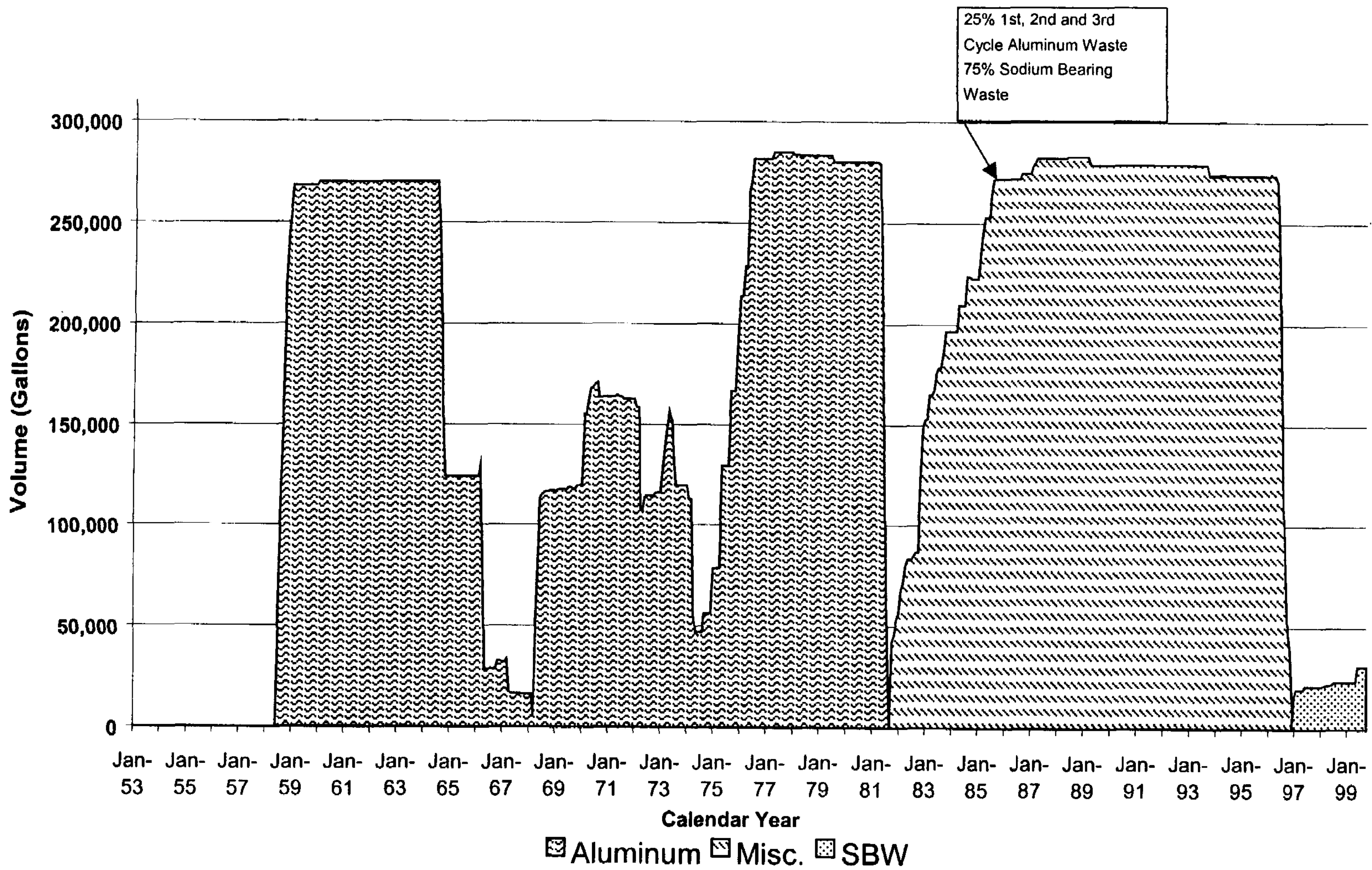

Figure B-4. Historical Operations of Waste Tank WM-183.

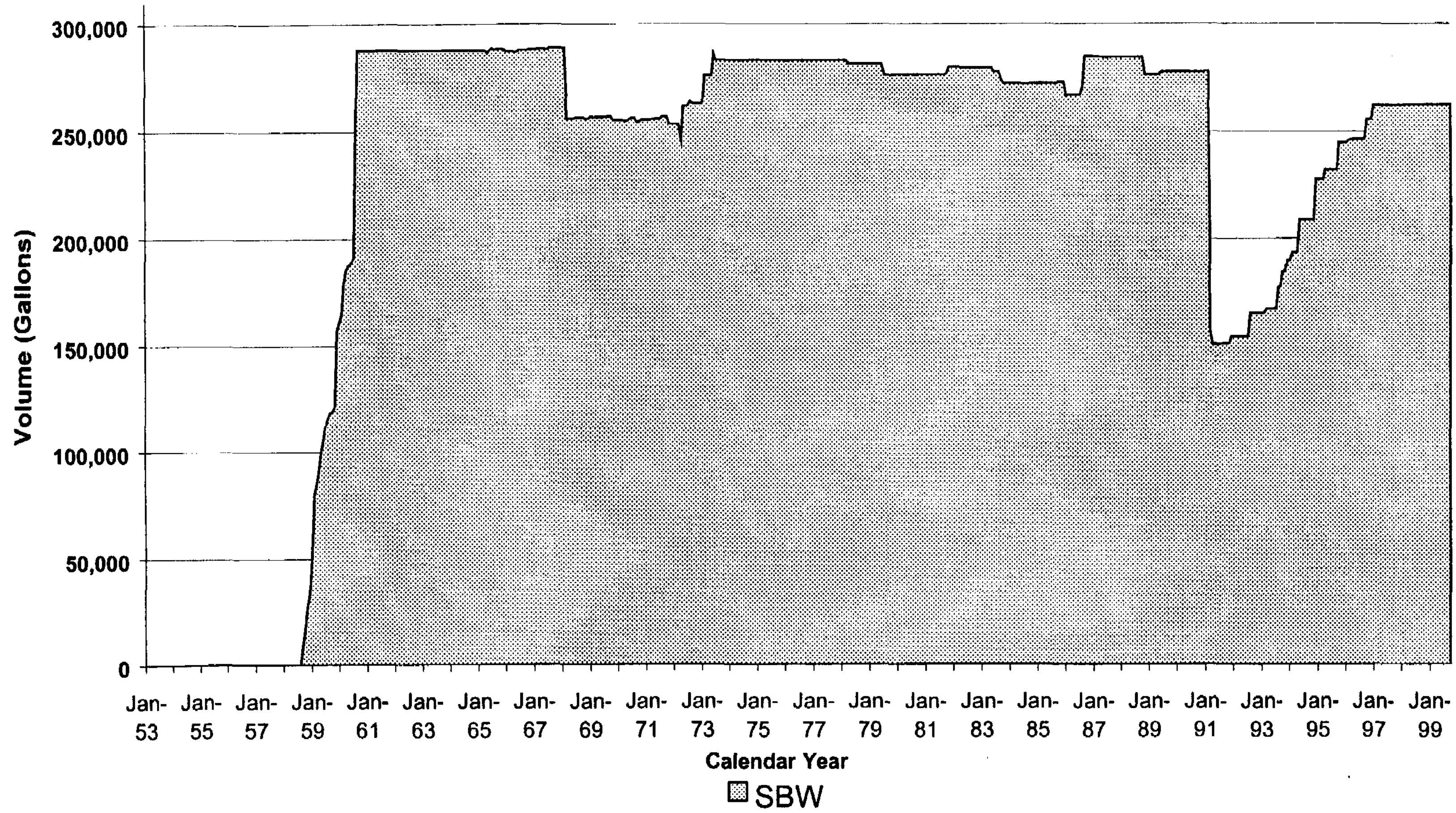

Figure B-5. Historical Operations of Waste Tank WM-184.

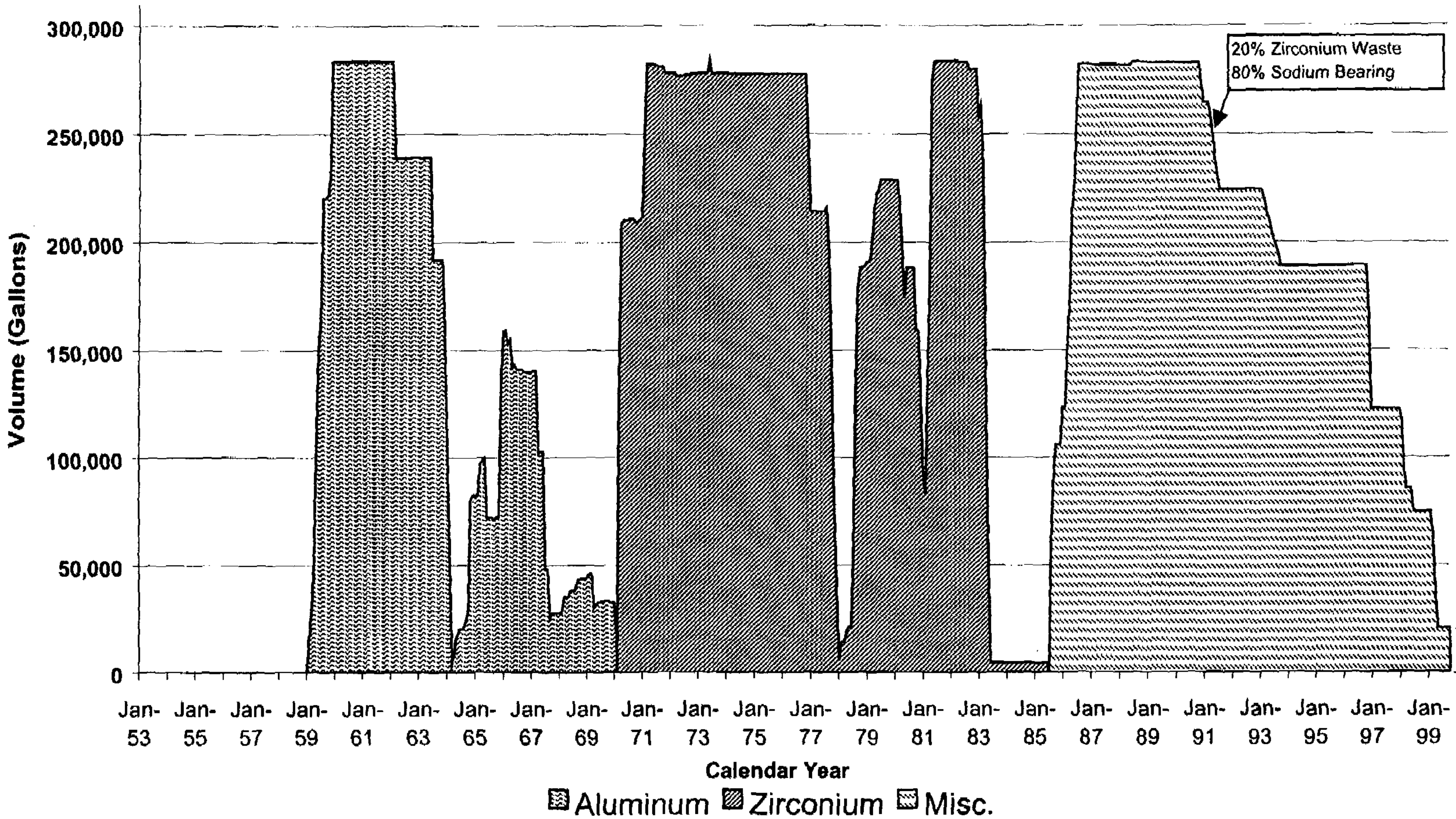

Figure B-6. Historical Operations of Waste Tank WM-185.

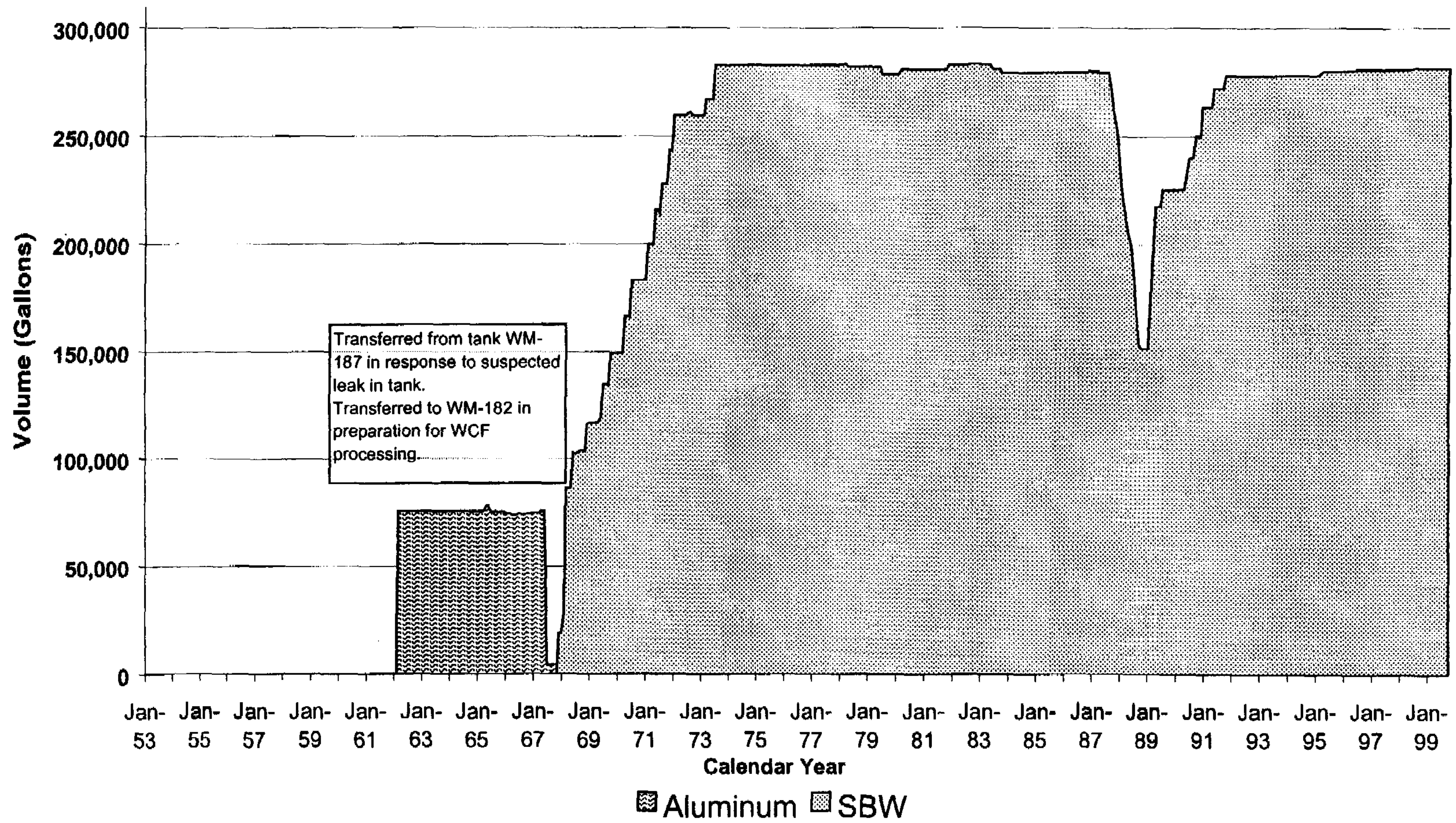

Figure B-7. Historical Operations of Waste Tank WM-186.

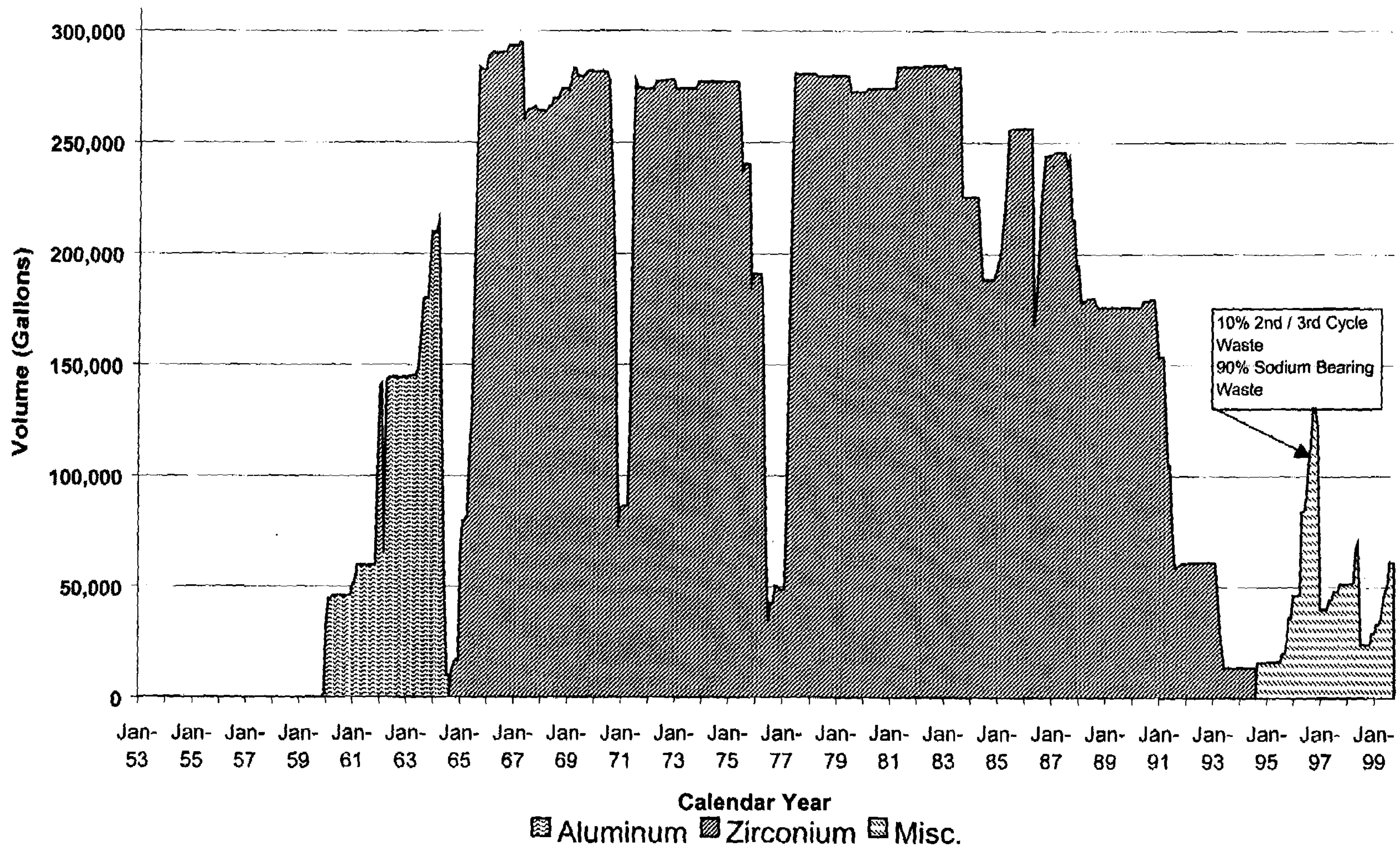

Figure B-8. Historical Operations of Waste Tank WM-187.

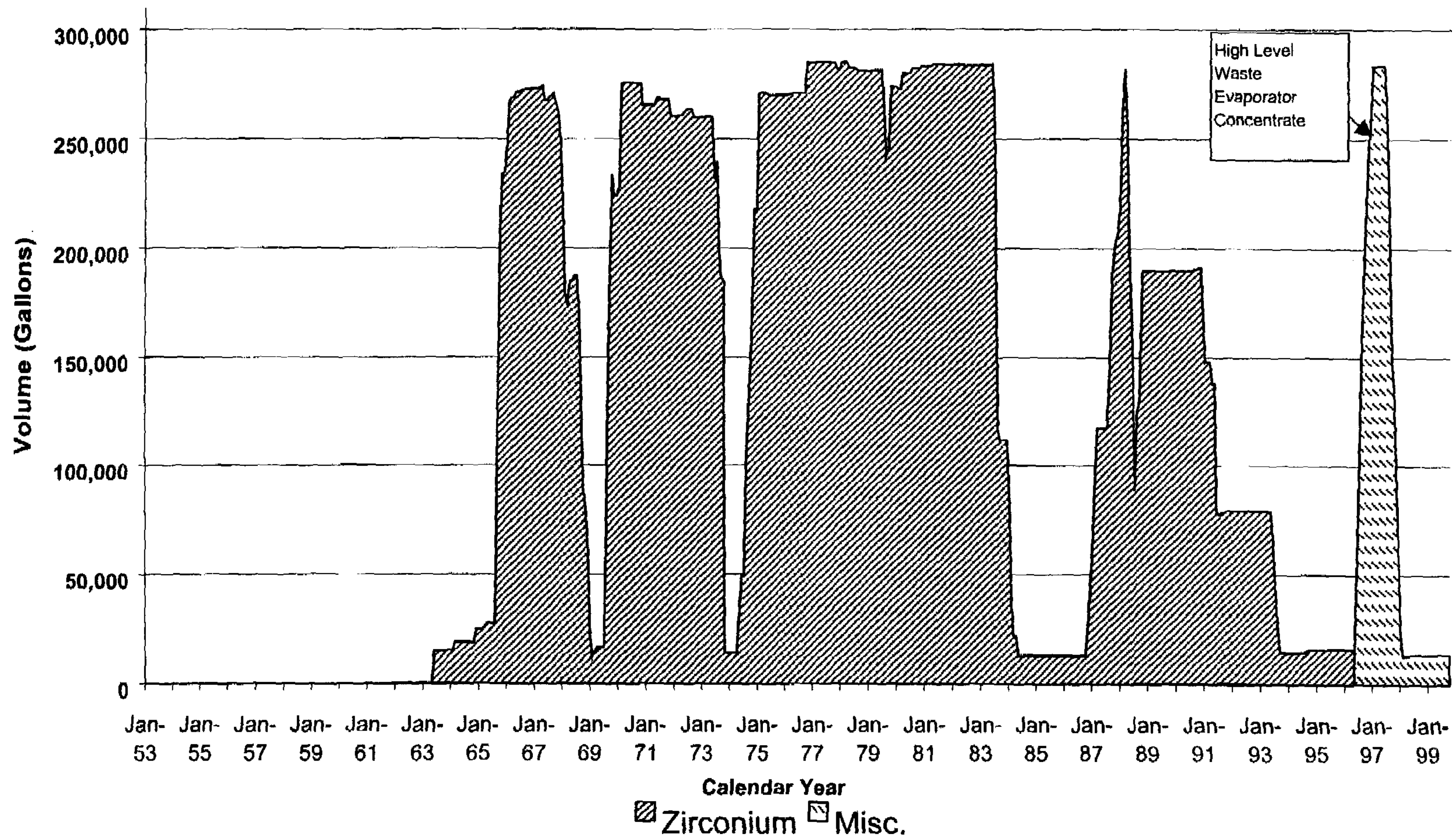

Figure B-9. Historical Operations of Waste Tank WM-188.

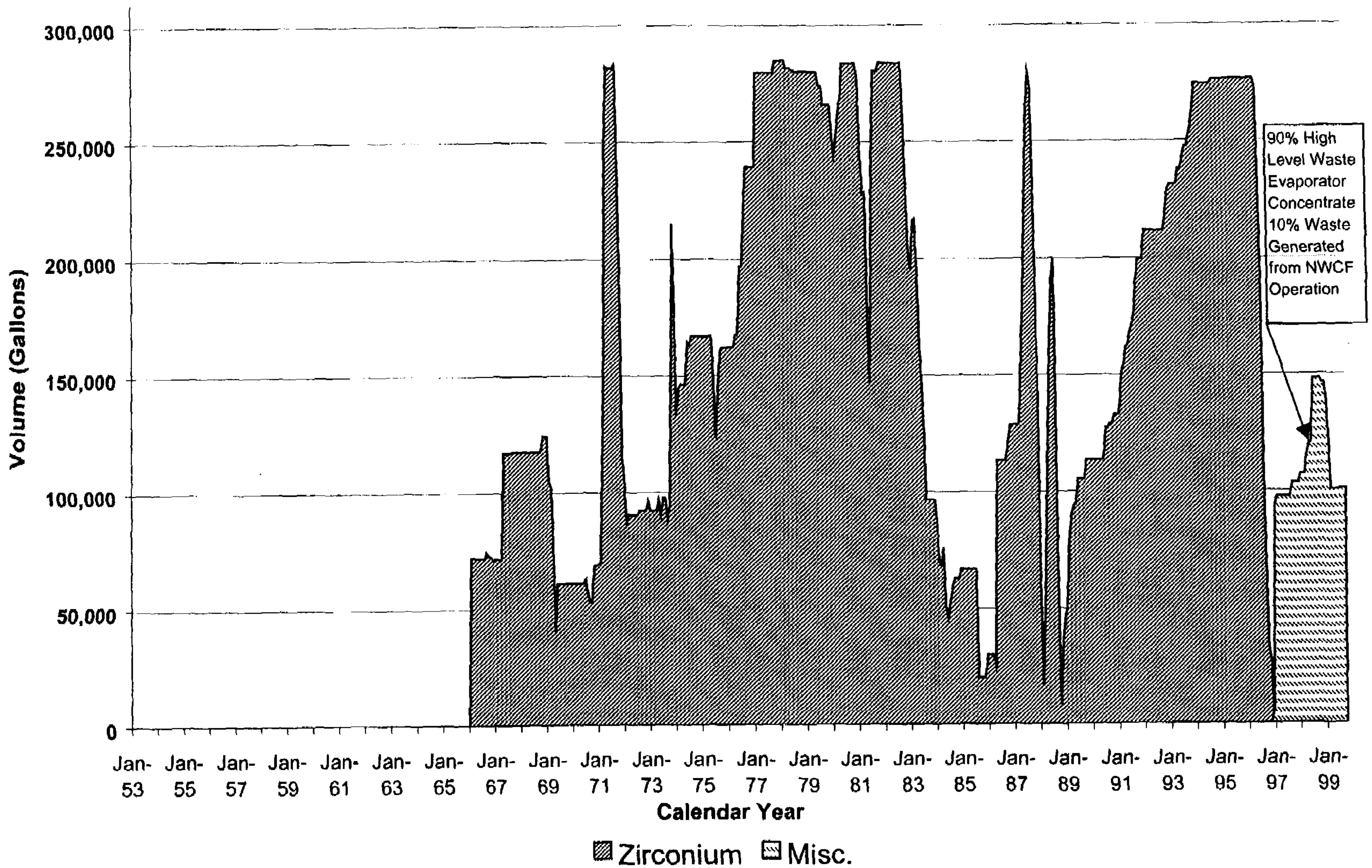

Figure B-10. Historical Operations of Waste Tank WM-189.

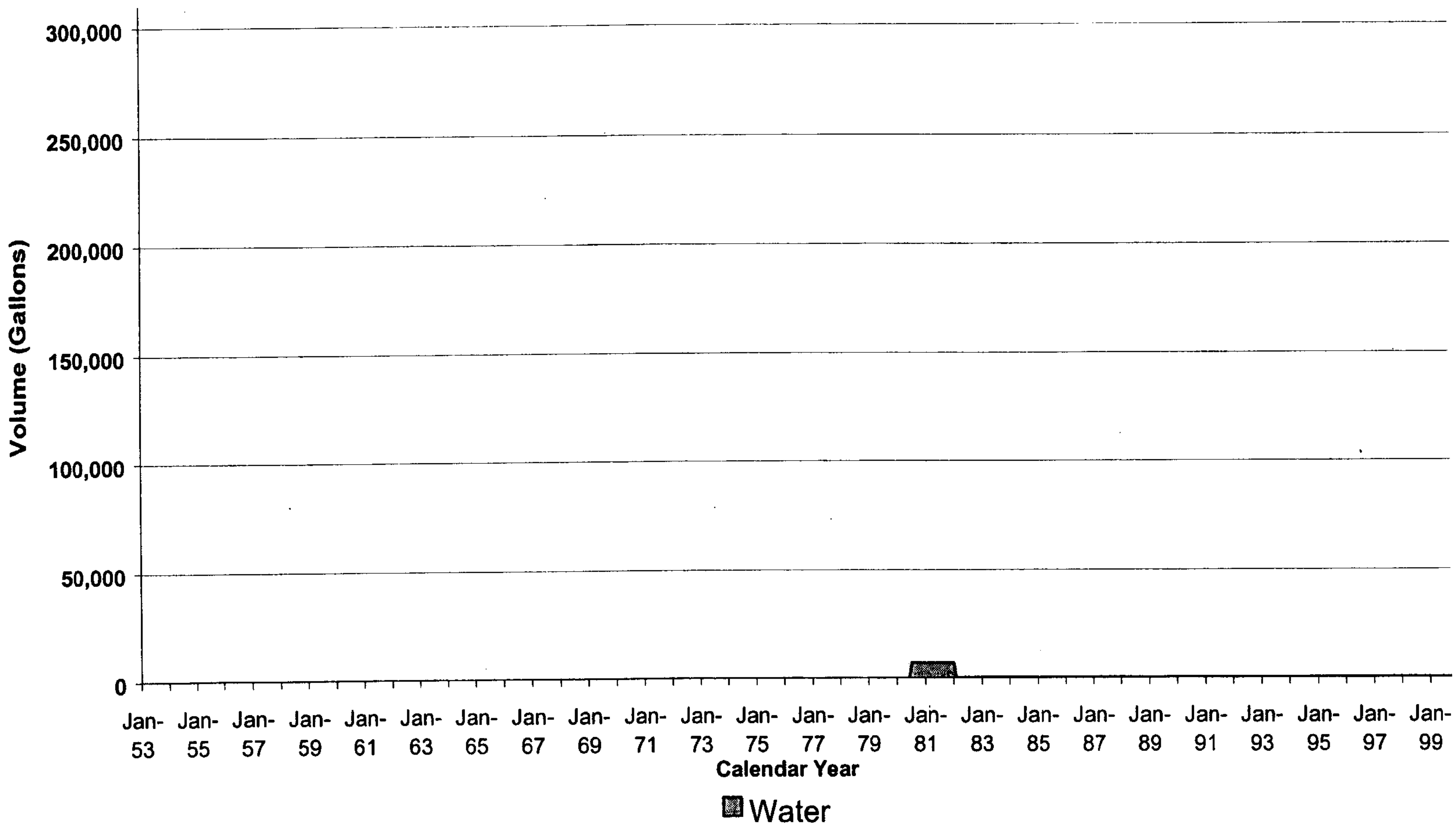

Figure B-11. Historical Operations of Waste Tank WM-190.